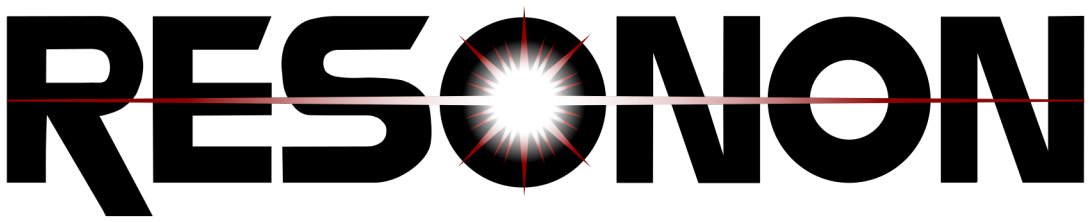


Benchtop Quick Start for Spectronon Version 3.4.11

Resonon Inc.

Jul 18, 2023

CONTENTS

CHAPTER

ONE

BENCHTOP SYSTEM OVERVIEW

Resonon's benchtop hyperspectral imaging system is comprised of a Pika hyperspectral imaging camera, linear translation stage, mounting tower, lighting assembly, and software control system. The positions of the imager and lighting assembly are adjustable along the length of the tower. See Figure 1 below.

Resonon's hyperspectral imagers are line-scan imagers (also referred to as push-broom imagers). Two-dimensional images are constructed by translating the sample relative to the camera. This is typically accomplished by placing the sample on a linear translation stage.

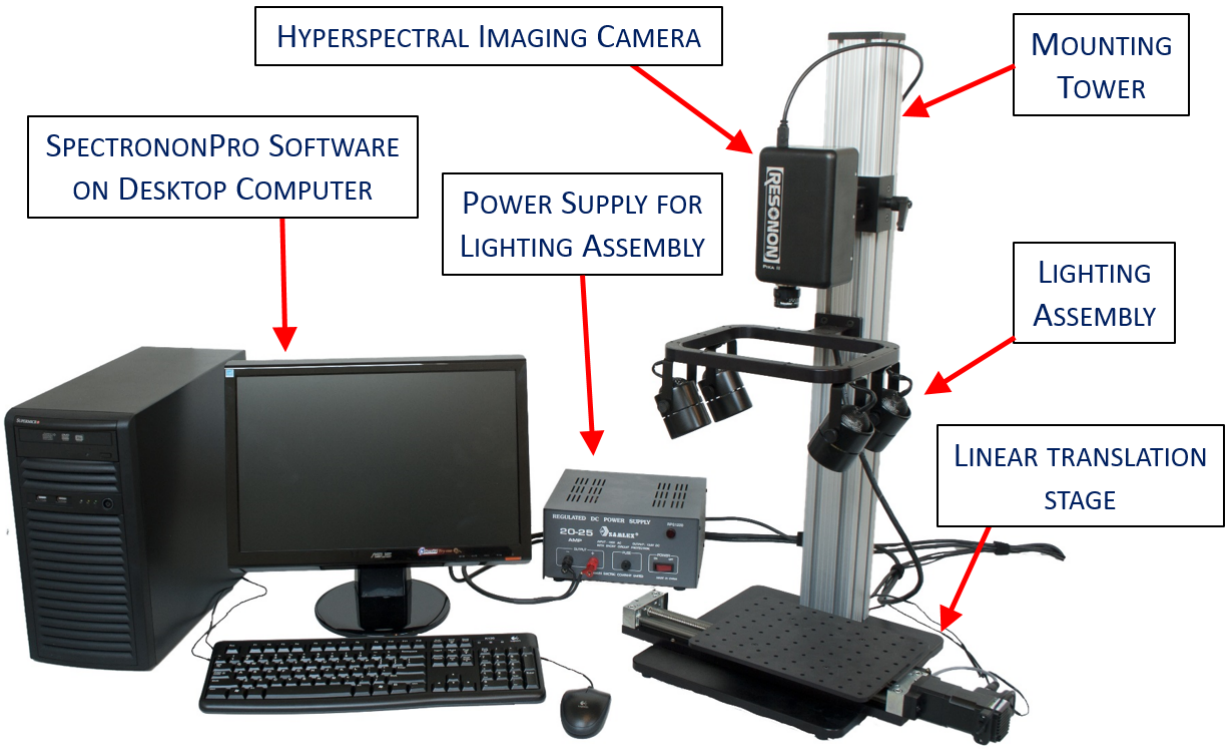
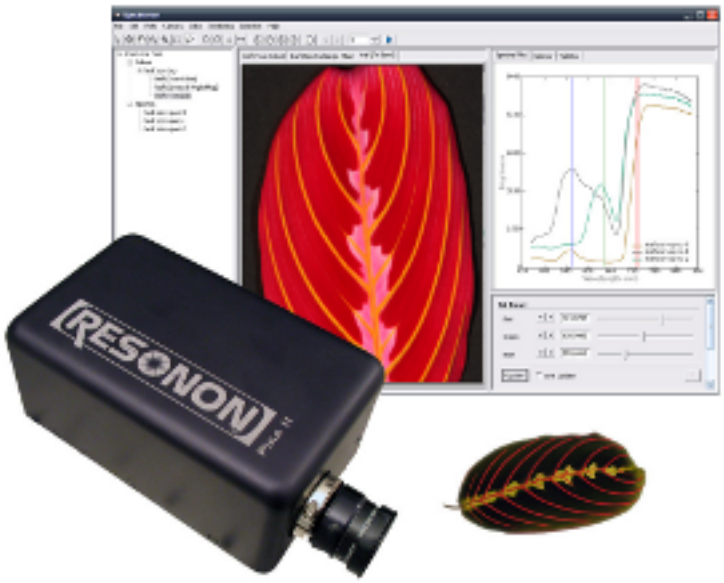


Fig. 1: Figure 1. Benchtop hyperspectral imaging system

Resonon's Pika imaging spectrometers are compact, high fidelity, digital instruments for industrial and scientific applications. Spectronon is a powerful hyperspectral data visualization and analysis software package we provide as a free download. Spectronon is easy to learn, offers efficient workflow, and is highly extensible by the user for custom applications. Additionally, a number of datacubes can be downloaded from the Resonon website (www.resonon.com) so you can begin exploring hyperspectral data within a few minutes.



SpectrononPro has all the features of Spectronon, but also includes data collection tools that are highly integrated with our Pika imaging spectrometers to streamline the collection of spectral images.

CHAPTER

TWO

BASIC DATA ACQUISITION

2.1 Data Modes and Sources

It is important to consider the **data mode** of the various hyperspectral imaging systems that produce hyperspectral **datacubes**. Hyperspectral data from Resonon imaging systems can be utilized in three forms, as summarized below. Which modes are used is application dependent, and affects subsequent datacube analyses.

2.1.1 Raw Data

These data are spectrally calibrated but are not corrected for the instrument-sensor-response or illumination functions, so the result cannot be directly interpreted as, for example, reflectivity. The units are digital number (DN) from the imager camera's sensor array. If a dark frame has been recorded, these data may have the camera's average dark current subtracted, but no other correction are applied. This is the least useful data form, as the spectral curves do not have physical units. `SpectrononPro` can collect datacubes in this mode with either a Benchtop System or Outdoor Field System.

2.1.2 Radiance

Raw data can be post-processed to give radiance data, where the DN unit is converted to physical units of microflicks (1 microflick = 1 microwatt per steradian per square centimeter of surface per micrometer of span in wavelength). This mode removes the imager's instrument-sensor-response function from the data. This function is corrected for by using the Imager Calibration Pack (ICP file) with the **Radiance Conversion** plugin. See the Spectronon user manual section "Advanced Data Analysis 1". The resulting data are the product of illumination and sample-reflectivity functions. In addition to the standard spectral calibration, radiance measurements require Resonon to perform a radiometric calibration (rad cal) on the imager with the desired objective-lens aperture. Radiance conversions are typically performed with `Spectronon[Pro]` on datacubes collected under stable, uniform lighting conditions, such as with Resonon's Outdoor Field System or Airborne Remote Sensing System.

2.1.3 Reflectivity/Reflectance

In reflectance mode, both the instrument-sensor-response and illumination functions are removed. This leaves the data in absolute reflectance. Resonon's Benchtop System commonly performs reflectance measurements on a sample by applying a response correction that employs a separate scan of a reflectance standard that corrects for the instrument-sensor-response and illumination functions. The reflectance standard, or calibration tile (cal tile), fills the entire field of view (FOV) of the imager. Spectralon® and Fluorilon® are the highest quality reflection standards, but Teflon is acceptable for many applications. (Teflon needs to be sanded with 100 grit sandpaper on an orbital sander to eliminate any specular properties).

In other system setups, such as with Resonon's Outdoor Field System or Airborne Remote Sensing System, data can be converted to reflectance in one of four ways described below.

1. **White reference:** Data can be processed to reflectance with a calibration measurement against a reflectance standard, such as used with the Benchtop System. This calibration is done with the *Record Correction Cube* feature, as described in the Spectronon user manual under "Imager Calibration". It is important to note that reflectance values are only accurate if the solar illumination (cloud, sun angle, etc.) does not change between the collection of the response-correction datacube and the sample datacube. Data can also be converted to reflectance using Spectronon's **Reflectance Conversion from Spectrally Flat Reference Cube** plugin. See the Spectronon user manual section "Advanced Data Analysis 1".

2. **Known spectral reference in scene:** After the data have been converted to radiance, the known spectrum of a reference object in the scene can be used to correct the rest of the cube to reflectance. The reference spectrum must be known and in a tab- or space-delimited file. Use the **Convert Radiance Cube to Reflectivity from Spectrally Flat Reference Spectrum** plugin. See the Spectronon user manual section "Advanced Data Analysis 1".

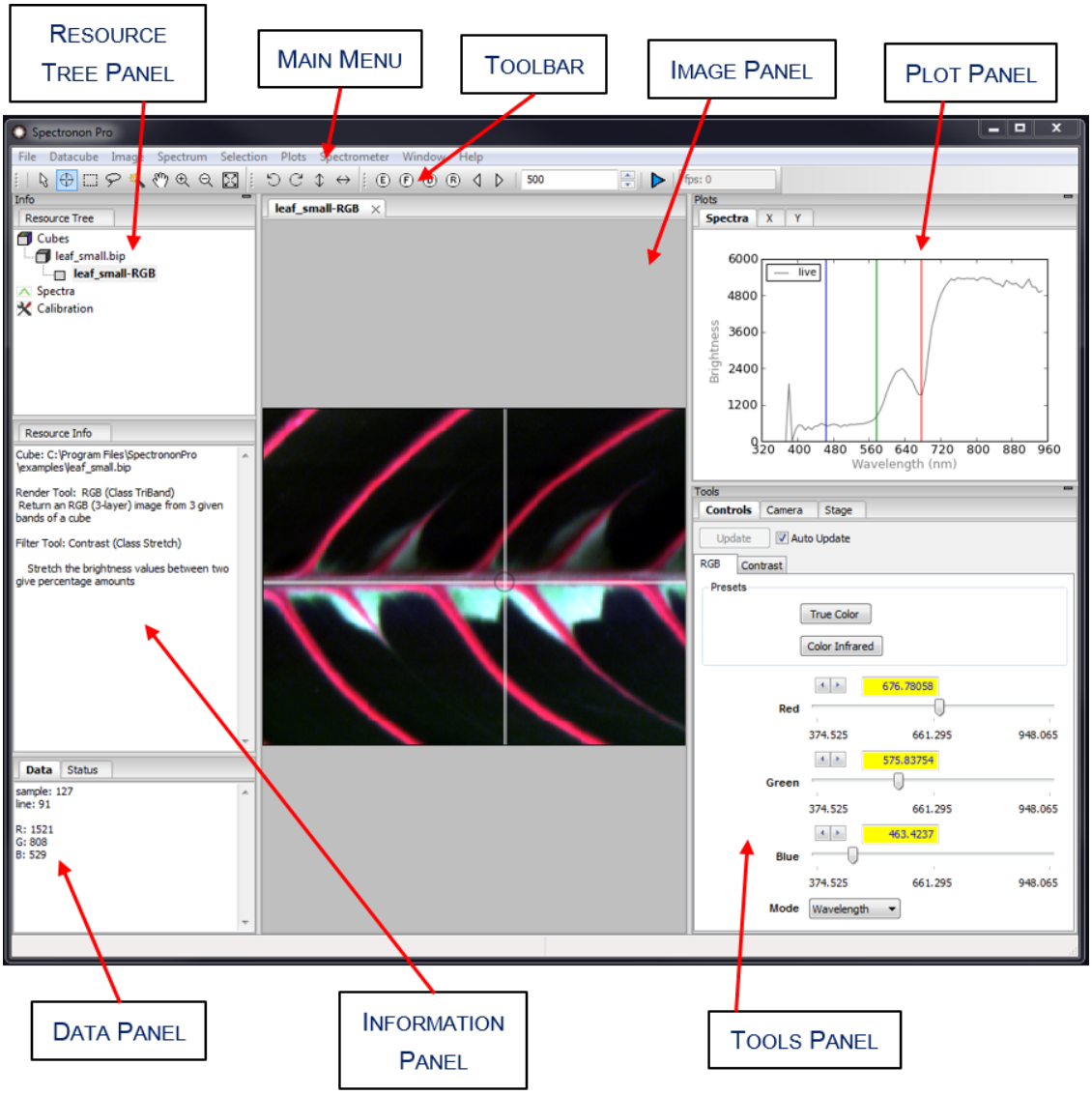
3. **Downwelling irradiance sensor:** An alternative method for converting data to reflectance is to use a downwelling irradiance sensor. This sensor records the solar spectrum during data acquisition. This data is used, along with the Imager Calibration Pack (ICP) file(s) supplied by Resonon for both the spectral imager and the downwelling sensor. This method uses the **Reflectivity Conversion from Downwelling Irradiance Data** plugin. See the Spectronon user manual section "Advanced Data Analysis 1".

4. **Atmospheric Correction:** Data can be converted to reflectance with the use of atmospheric correction algorithms such as FLAASH (Fast Line of Sight Atmospheric Analysis of Spectral Hypercubes). Please contact Resonon for more information.

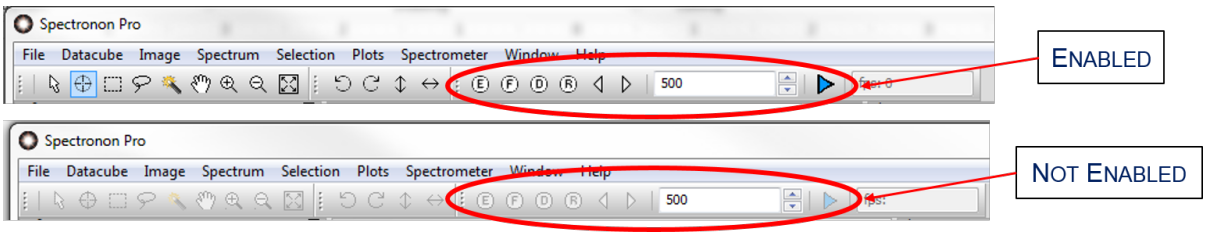
2.2 Start The System

If you have an illumination system, turn it on and let it warm up sufficiently. Some lights may require 15 to 20 minutes to fully stabilize.

With the imager and (optional) stage connected to your computer, launch **Spectronon[Pro]** by double-clicking on the **Spectronon[Pro]** icon or starting **Spectronon[Pro]** from your Start menu. The **SpectrononPro** icon and user interface are shown below with the various windows labeled.



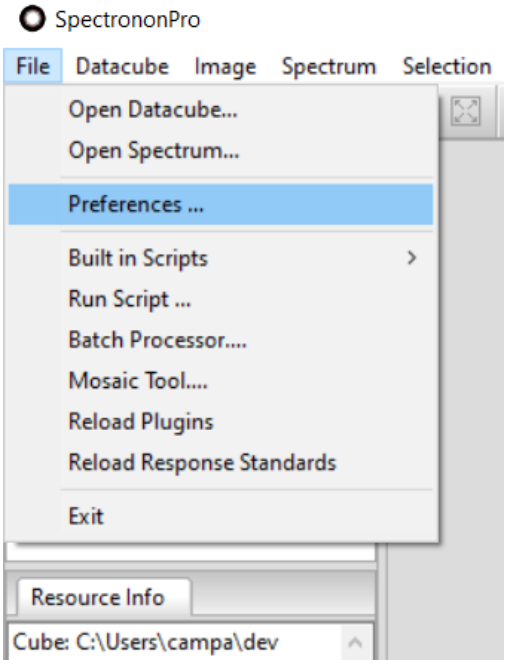
Once the software has started, make sure that the imager and stage controls (if used) are enabled, which indicates that they are properly connected. The imager and stage tools will be greyed out if not enabled, as shown below.



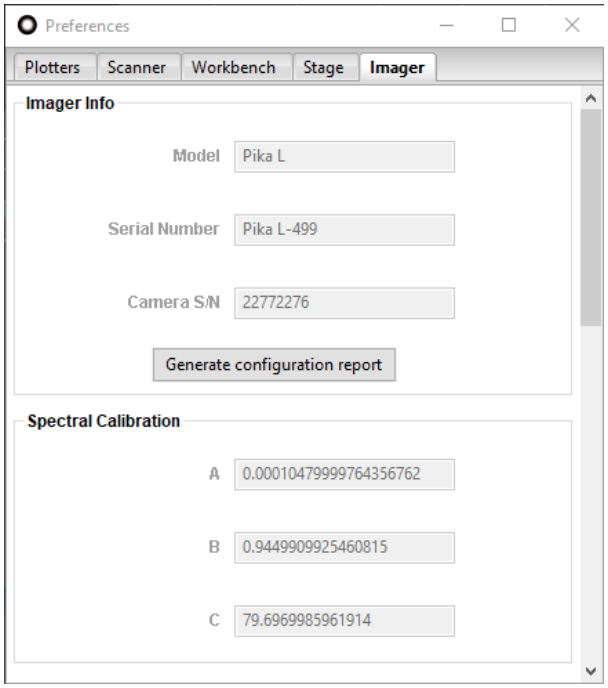
You can get the latest version of **Spectronon[Pro]** by clicking on *Help* → *Check For Updates*. This won't download the latest version, but will give an alert if there is a newer version, as well as a hyperlink to it.

2.3 Verifying Imager Calibration

From the Main menu, select *File* → *Preferences*....



This will reveal the *Preferences* window. This window has several tabbed panes that provide detailed information about the connected *Imager* and *Stage*, as well as settings for the *Scanner*, managing and analyzing datacubes on the *Workbench*, and visualizing data with *Plotters*.



In the *Preferences* window, select the *Imager* tab to reveal detailed information about your connected hyperspectral imager. Your imager was calibrated at the factory. The spectral calibration numbers are provided on a sheet that comes with your imager and should be verified prior to use. Check the *A*, *B*, and *C* values from the sheet provided against the *Spectral Calibration* values appearing in **SpectrononPro**. If you cannot locate your calibration sheet or these numbers differ from those reported in the software, then please contact Resonon at: ProductSupport@resonon.com.

2.4 Imager Controls

Camera Settings for the imager can be controlled by clicking on the *Imager* tab in the *Tools* panel in the Main window.

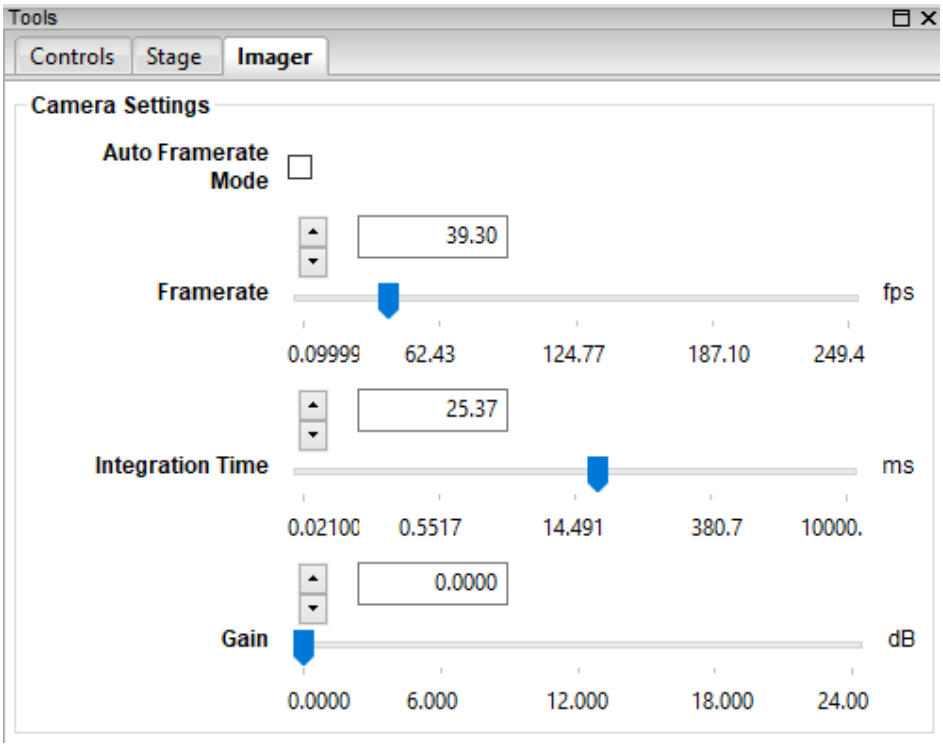


Fig. 1: Imager Camera Settings with Auto Framerate Mode off.

Framerate is equal to the number of datacube lines acquired each second, or frames per second (fps). The *Framerate* limits the maximum *Integration Time*, where typically *Integration Time* $\leq$ 1 / *Framerate*.

Integration Time is the duration of data acquisition for each individual line (also known as exposure time), displayed in milliseconds (ms). Larger integration times require smaller frame rates, and smaller integration times allow faster frame rates. Integration times that are too short have poor signal-to-noise ratio. Integration times that are too long saturate pixels in the detector.

Gain is a factor that increases the signal, but at the expense of signal-to-noise ratio. Keep the gain as low as possible, preferably zero. A gain of 6 dB roughly doubles the signal. (The IR imagers do not have this setting.)

Some of Resonon's imagers support *Auto Framerate Mode*. When enabled, the *Framerate* cannot be set directly. (However, the frame rate can still be viewed.) The user need only select an appropriate *Integration Time* (and *Gain*, possibly) based on the illumination and sample brightness, and **SpectrononPro** automatically chooses the fastest *Framerate* for that *Integration Time*. This helps produce the fastest possible scans for a given setup.

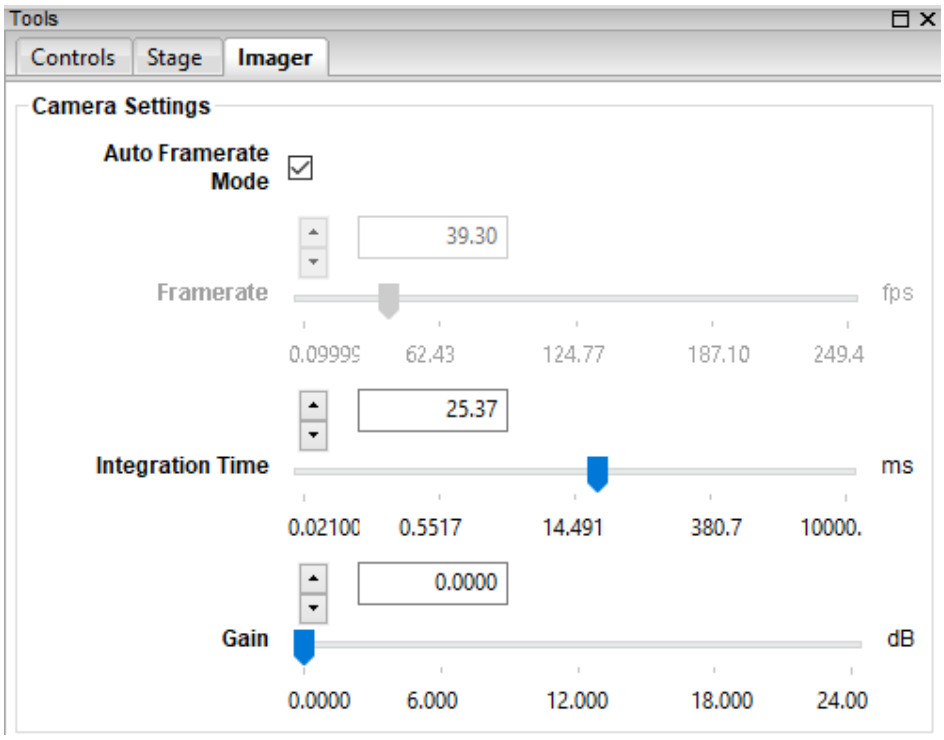
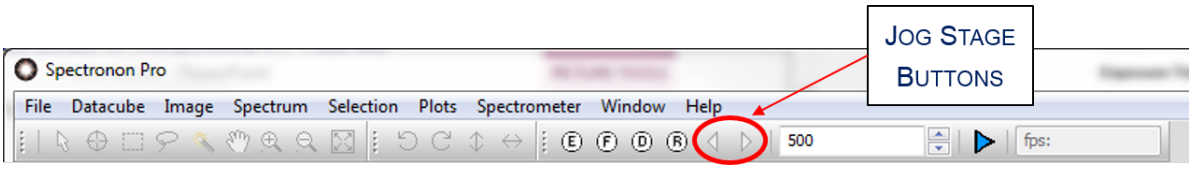


Fig. 2: Imager Camera Settings with Auto Framerate Mode on.

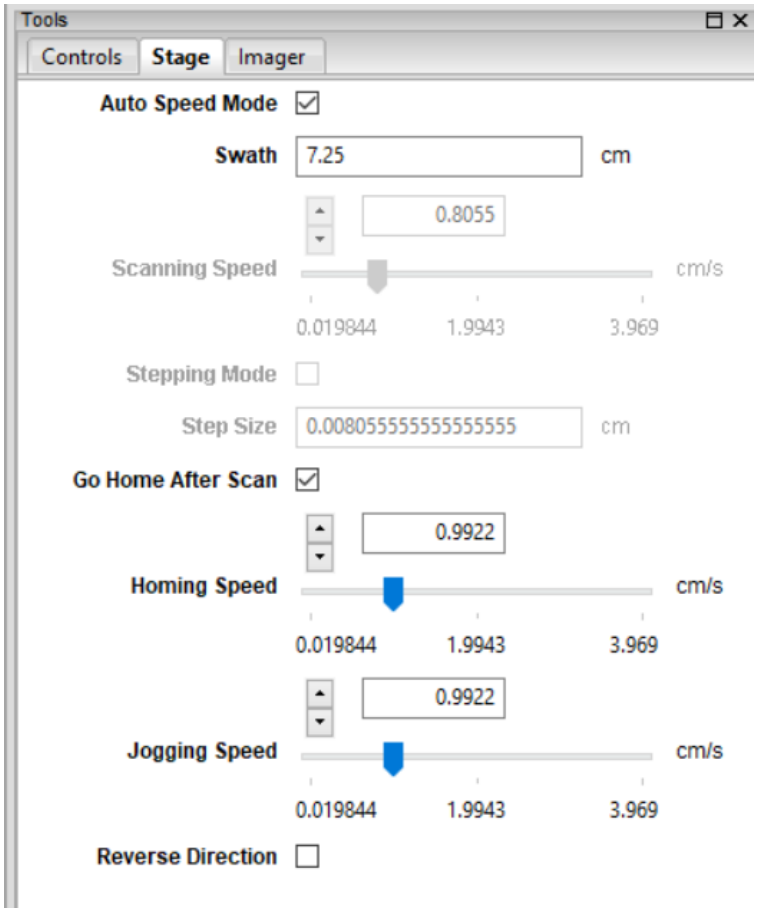
Additional *Imager* settings are available in *Preferences–>Imager*, described in `Section {number}: {name}`.

2.5 Stage Controls

The stage is configured at the factory for either the Benchtop System (cm units) or the Outdoor Field System (deg units). You can move the stage manually by clicking on the *Jog Stage* buttons, located on the toolbar. The buttons move the stage incrementally in either direction. Use the buttons to center the stage underneath the Pika imaging spectrometer.



The stage can be further controlled by clicking on the *Stage* tab in the *Tools* panel. The default stage setting in **`SpectrononPro`** is *Auto Speed Mode*. This means that the *Framerate* of the imager's camera is used to automatically calculate the stage's *Scanning Speed*. Because the imager is a line-scan imager, the stage must traverse at a speed proportional to the camera's framerate in order to capture the scene with a unit aspect ratio. If the stage is too slow with respect to the *Framerate*, then the image is elongated in the direction of stage travel. If the stage is too fast with respect to the *Framerate*, then the image is shortened.



For the Benchtop System, the *Swath* value is key to achieving unit aspect ratio scans when using *Auto Speed Mode*. The swath is the width of the stage that is viewed by the imager, and is affected by the choice of **objective lens** and the **working distance** from the (in-focus) object on the stage to the imager. A procedure for determining a value for *Swath* is provided later in `Section {number}: {name}`. In the Outdoor Field System, this *Swath* is replaced by the angular *FOV* (field of view), which is typically the far-field value specified for the given objective lens.

With *Auto Speed Mode* selected, several controls are disabled and serve only as value indicators. The *Scanning Speed* indicates the continuous scanning speed, and is set automatically. If the stage cannot move sufficiently slowly in a continuous manner, then *Stepping Mode* will be enabled. In Stepping mode the datacube is acquired line-by-line with the stage coming to a stop for each line, i.e., stepping. (Stepping occurs for a sufficiently long *Integration Time* corresponding to a sufficiently low *Framerate*.) The *Step Size* parameter indicates how much each line in the scan covers (continuous or stepping).

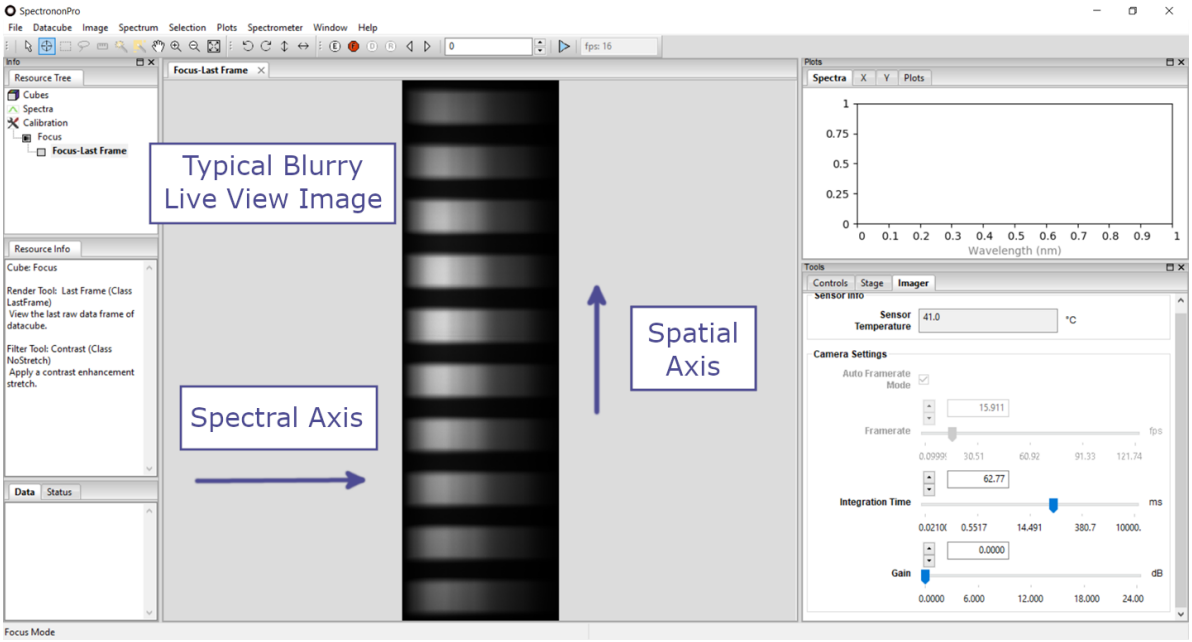
If *Go Home After Scan* is selected, then the stage will return to its starting position after each scan. The speed at which the stage returns to its original position is the *Homing Speed*. (The *Homing Speed* setting is also used to set the between-steps *Scanning Speed* when the stage is automatically put into *Stepping Mode*.) *Jogging Speed* is used for the *Jog Stage* buttons, described above. *Reverse Direction* reverses the scan direction of the stage, including the jog directions.

Additional *Stage* settings are available in *Preferences–>Stage*, described in `Section {number}: {name}`.

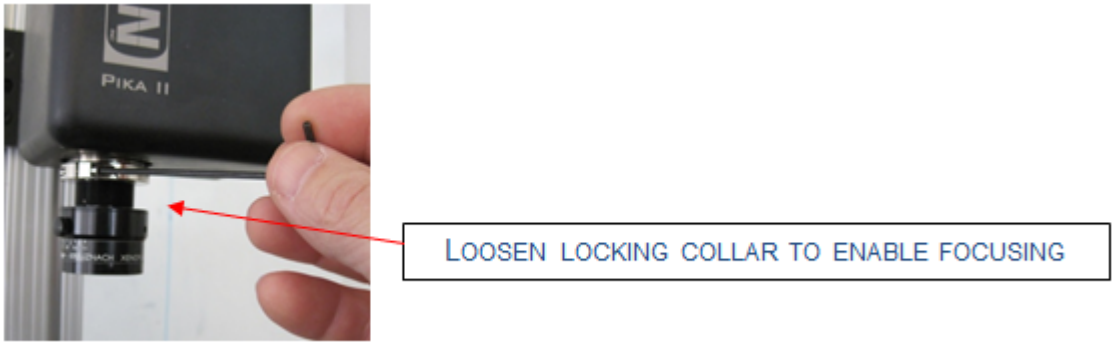
2.6 Focusing Objective Lens

You are now ready to **focus the objective lens** of your Pika imaging spectrometer. At first, this process can be somewhat challenging, but with a little practice it becomes straightforward. Begin by clicking on the *Focus* button  located on the **SpectrononPro** tool bar. This will reveal a live image of individual frames from the imager's camera. (Wave your hand in the **field of view** (FOV) of the imager to confirm that the image is a live view.) One axis of this image represents the spatial (position) axis of your object, and the other is the spectral (wavelength) axis. (To understand this view better, move colored objects within the FOV of your imager after you have focused the objective lens.)

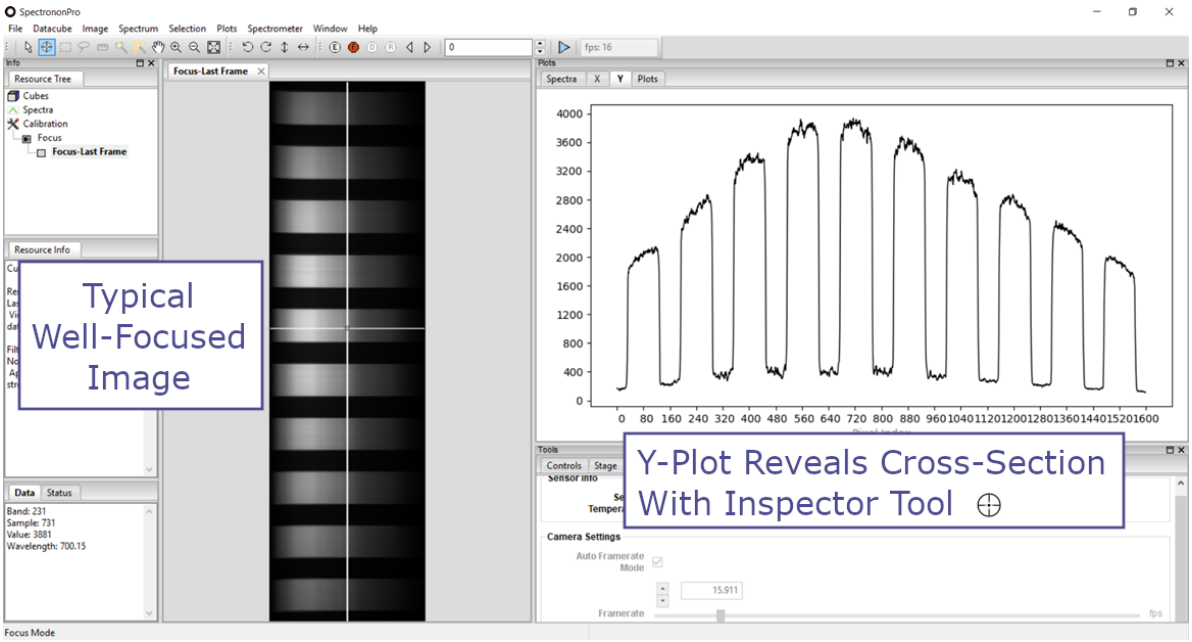
Place an object with multiple light and dark regions within your Pika imaging spectrometer's FOV. For the Benchtop System, make sure that the illumination is adequate and sufficiently uniform, and place a sheet of paper with dark lines on the stage, as provided in *Focusing & Calibration Sheets*. For the Outdoor Field System, if you are in the field and are observing objects at a distance, then direct the imager towards an object with multiple features, such as a tree with many branches. Unless your lens is already focused, you will see a series of blurry or barely discernible lines in the live-view image in the center panel of **SpectrononPro**.



To adjust the focus, first unlock the focus adjustment. With Schneider lenses, this is done by loosening the locking metal collar on your objective lens using an Allen wrench, size 5/64 inch.



Then rotate the objective lens until you see dark lines from your object come into focus, as shown. Maximize the sharpness of the lines.



Hint: Clicking the *Inspector Tool* on the live view image, and then selecting *X* tab in the *Plots* window will reveal a cross-section plot of your image. Viewing this plot allows you to graphically see the sharpness of your focusing. You can zoom in on the X-axis by clicking the *Zoom Tool* and then clicking on the X-axis.

Note: In the Benchtop System, the **working distance** is often changed to fill the imager's FOV with the sample being scanned on the stage. If you change the working distance, then you will need to refocus the imager and update the *Swath* value under the *Stage* tab in the *Tools* panel. A good first estimate of the value for *Swath* can usually be made from the ruled lines of the in-focus focusing sheet.

Focusing the Outdoor Field System can be a little more challenging than the benchtop system. If you are focusing on objects that are further than 40 feet start the process with the objective lens screwed in close to the collar. A method that has proven useful is to start the focusing process by increasing the number of lines scanned to 1000. This gives a large scan area to begin the process. You will need to be out of live focus mode when performing this focusing procedure ("*F*" button should not be red). When the scan begins make a quarter turn with the lens. Continue to make quarter turns until you are confident your scene is in focus. When making the quarter turn, intentionally place your hand in front of the lens. This will create a thin black line in the scan separating one focus length from its neighbor, allowing for easier comparison. This process can take some time, so be patient and remember that it gets easier with practice.

Once you have completed focusing, re-tighten the lock to the focus adjustment. Then click on the *Focus* tool again to toggle the camera live view off.

Note: See our YouTube video on focusing the benchtop system at http://www.youtube.com/resonon.

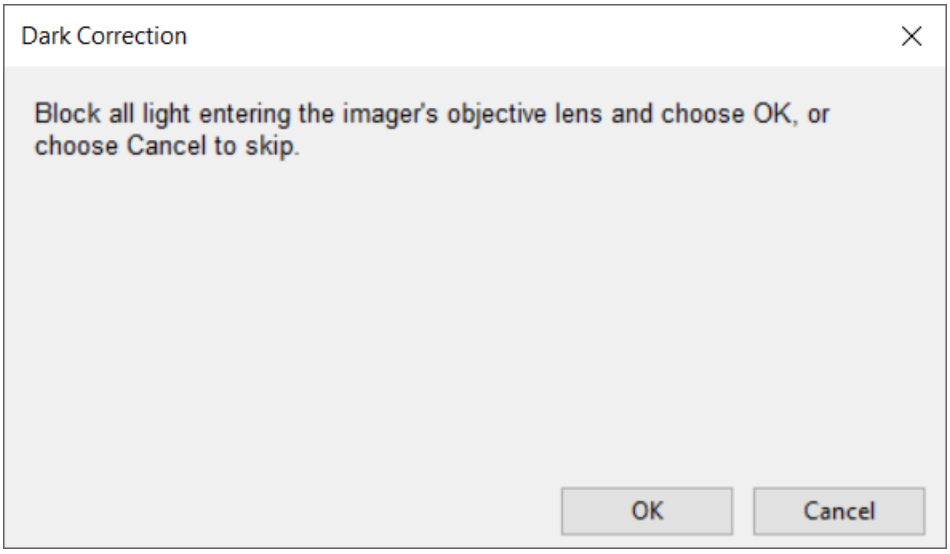
2.7 Reflectance Measurement Calibration

The following discussion describes how to set up your system to scan for **reflectance** scaled to a reference object. If you wish to collect raw data and convert it to radiance do not perform the following correction process.

Note: The **Dark Current** button Ⓓ and the *Response Correction Cube* button Ⓡ are disabled in live camera view mode. If needed, then click on the *Focus* Ⓕ tool to toggle the camera live view off.

2.7.1 Dark Correction

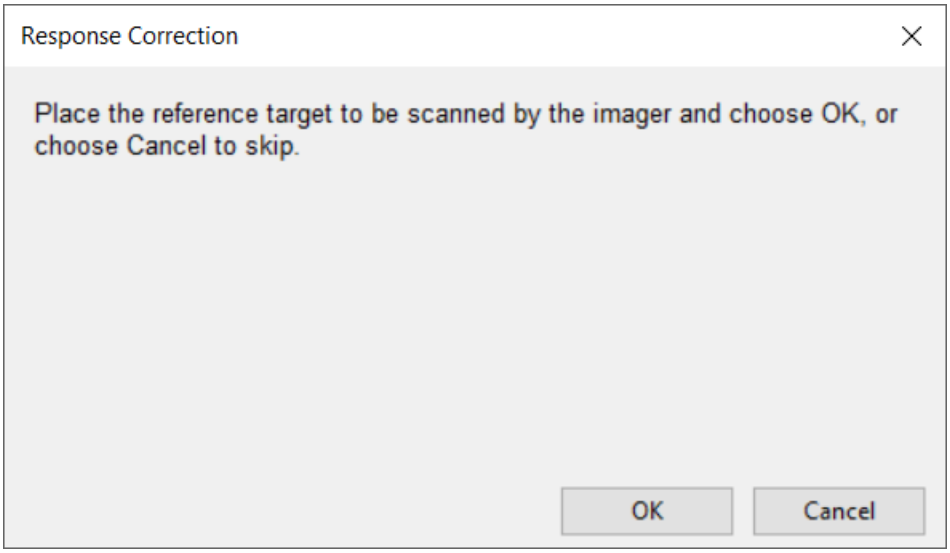
SpectrononPro can remove the imager camera's average dark current from scans. Begin by clicking on the *Dark Correction* button Ⓓ on the **SpectrononPro** toolbar. You will be instructed to block all light entering the imager's objective lens.



After you have the objective lens blocked, click *OK* as instructed. **SpectrononPro** will then collect multiple dark frames and use these measurements to subtract the average dark current from your measurements. The *Dark Correction* button on the toolbar will appear with a red check through it as soon as the dark frames have been collected. Once you see the red check, unblock the objective lens.

2.7.2 Response Correction

Measuring **absolute reflectance** of an object requires correction to account for instrument-sensor-response and spatially nonuniform illumination effects. To do this, click on the *Response Correction* button Ⓡ on the *SpectrononPro* toolbar. A message will appear telling you to place a reference material within your Pika imaging spectrometer's FOV. The reference material should be uniform across the imager's FOV. Examples of reference materials include Spectralon®, Fluorilon®, or sheets of white Teflon®.



Once the reference material is in place, click on *OK*. This will trigger a short scan of the reference material. Once complete, the *Response Correction* button will appear with a red check mark  , indicating that the data you collect will be scaled in reflectance with respect to the reference material, including flat-fielding to compensate for spatial variations in your lighting. Any dark correction is subtracted from the response correction.

Note: For additional help with this process see our Calibration video at http://www.youtube.com/resonon.

2.7.3 Invalidating Corrections

Once the imager is calibrated for both dark current and reflectance reference, the imager will remain calibrated until the corrections are removed by the user, or **SpectrononPro** is restarted. To manually remove the corrections, click *Spectrometer → Remove Dark Correction Cube* and *Spectrometer→ Remove Response Correction Cube*.

Dark current typically changes with the imager camera's integration time and gain settings, the degree of which depends on the imager camera's particular sensor. Furthermore, the response correction is likewise invalidated by changes in the imager camera's integration time. By default, **SpectrononPro** will warn you before taking a scan if such changes have likely invalidated one/both of the corrections. **SpectrononPro** does **not** detect changes such as illumination and working-distance adjustments, which also invalidate the response correction.

Hint: Before collecting the dark and response correction cubes, you may first want to set the imager camera's *Framerate* and *Integration Time* while in live view and viewing the reflectance reference. Increase the *Integration Time* until the signal is near, but sufficiently below, saturation over the entire frame (spatially and spectrally). Next, maximize the scan speed by choosing the fastest *Framerate* for that *Integration Time*. (If available, then *Auto Framerate Mode* can be turned on to have **SpectrononPro** automatically set the fastest frame rate.) Also consider the auto expose feature accessible as the *Auto Expose* button in the toolbar  in the *Scan* toolbar and described further in `Section {number}: {name}`.

2.8 Scanning and Saving Datacubes

2.8.1 Scanning with Unity Aspect Ratio

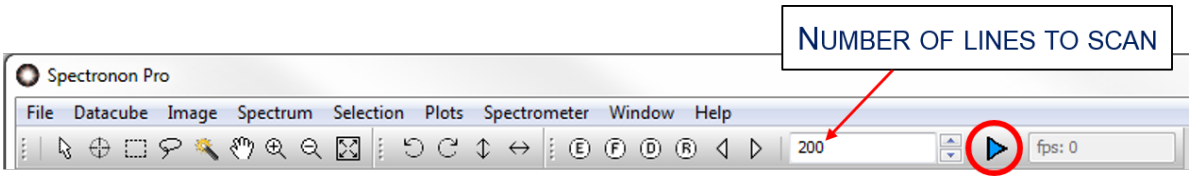
A distortion-free hyperspectral datacube with a unit-aspect-ratio image is achieved when the stage/object advances the distance of the projected image of one spatial pixel per each line acquired at the imager's given frame rate. Thus, changing the *Framerate* setting requires updating the stage's *Scanning Speed* to maintain unity aspect ratio, while changing only the *Integration Time* does not. Similarly, changing the working distance of the imager to the stage changes the object magnification (and FOV or swath width), and thus changes the aspect ratio for any particular *Framerate* and *Scanning Speed* combination.

Hint: Typically, you want the fastest frame rate possible that supports the integration time required for the illumination and sample brightness. This is because faster frame rates produce faster scans.

By default, **SpectrononPro** has *Auto Speed Mode* enabled, which automates required *Scanning Speed* adjustments each time the *Framerate* changes. This depends on a single calibration parameter, the *Swath* setting (in cm) for the Benchtop System, or the *FOV* setting (in deg) for the Outdoor Field System. Once this parameter is properly "tuned" for a given system setup, you can freely adjust the *Framerate* without having to manually update the *Scanning Speed*, which is updated automatically. For very low frame rates (long integration times), **SpectrononPro** automatically compensates by turning on *Stepping Mode* and setting the proper *Step Size*.

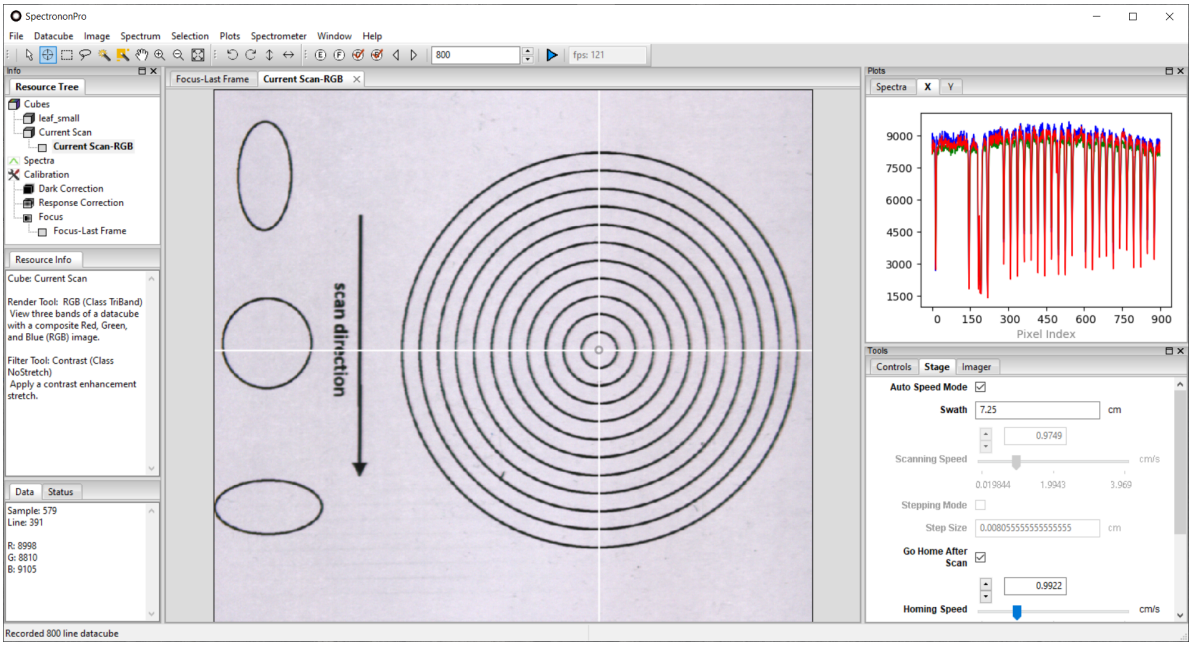
Benchtop System

To determine the *Swath* setting for the Benchtop System, it is useful to first scan an object whose distortion is easy to observe, such as a circle. Print out the **Pixel Aspect Ratio Calibration Sheet** provided in *Focusing & Calibration Sheets* for this purpose. After placing an object with circles within the FOV of your imager, record a scan with enough lines that you can see the complete circle. (500-800 lines are usually sufficient.) Record the scan by clicking on the *Scan Button*  , and a waterfall RGB image should appear in the Image Panel of **SpectrononPro**. You may need to record several trial images to determine how many lines to scan and where to best position the object.



Hint: Stop a scan by re-clicking on the *Scan Button*  , which changes to the *Stop Button*  during the scan.

If the aspect ratio of the image is distorted, then you will need to change the *Swath* setting on the *Stage* tab on the *Tools* panel. If your image is elongated along the scan direction, then the stage was moving too slowly in relation to the frame rate (over-sampling), and you should increase the *Swath* setting, which automatically increases the *Scanning Speed*. Conversely, if your image is compacted along the scan direction, then the stage was moving too quickly in relation to the frame rate (under-sampling), and you should decrease the *Swath* setting, which automatically decreases the *Scanning Speed*. Repeat the above process until your image is no longer distorted, as pictured below.



It is also possible to measure the swath directly by imaging the vertical lines of the provided *Focusing & Calibration Sheets*. Count the number of lines, and use the width between each line to estimate the total width, which is the swath width. This can even be done at the end of the imager focusing described in `Section {number}: {name}`.

Outdoor Field System

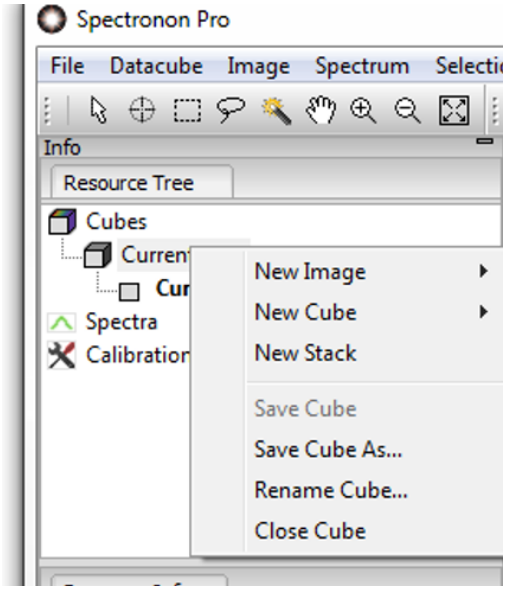
To determine the *FOV* setting for the Outdoor Field System, simply use the (far-field) FOV value specified for the imager's objective lens, which assumes the objective lens is focused at infinity.

Note: For help setting the aspect ratio without using *Auto Speed Mode* see our Setting Aspect Ratio video at http://www.youtube.com/resonon.

2.8.2 Scanning Objects

To scan an image of an object after calibrating the system, place the object on the stage within the imager's FOV and type in the number of lines you would like to scan in the window just to the left of the *Scan Button*  . Record a hyperspectral datacube (the image) by pressing the *Scan Button*  . (Click  to terminate the scan early, if needed.) Adjust the stage position and increase/decrease the number of lines as needed to cover the object's feature(s) of interest.

A waterfall image of your datacube will appear in the Image Panel of Spectronon, and a new entry labeled *Current Scan* will appear in the *Resource Tree*. To save the scanned datacube, use your mouse to select *Current Scan* and then either right-click or select *Datacube* → *Save Cube*. This will open a dialog window that allows you to name the datacube and save it in a folder of your choosing. If you do not save your datacube, the current scan will be overwritten when you record another datacube, and a warning should appear.



Hint: For additional help scanning and saving datacubes see our Scanning and Saving video at http://www.youtube.com/resonon.

Once a datacube is scanned, you can use all the visualization and analysis tools of **`Spectronon[Pro]`** on your datacube image, as introduced in `Section {number}: {name}`.

CHAPTER

THREE

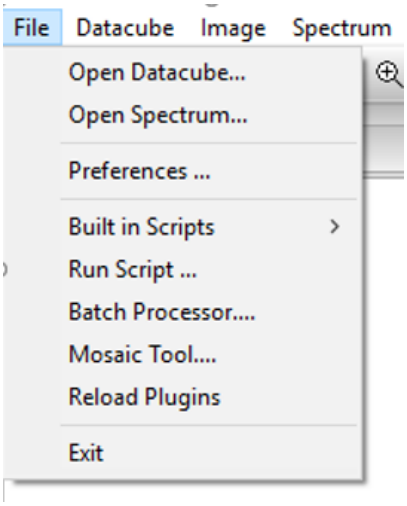
BASIC DATA ANALYSIS

Spectronon provides visualization and manipulation capabilities for hyperspectral images. SpectrononPro software has all the features of Spectronon, but also enables data acquisition from Resonon's family of imagers. Spectronon software can be downloaded for free on Resonon's website http://www.resonon.com/. SpectrononPro comes bundled with any of Resonon's imaging spectrometers. Additional analysis capabilities are available in software packages such as ENVI®.

This section begins with basic operation of Spectronon, such as opening a hyperspectral datacube and viewing the data. A complete description of visualization tools is provided in the Spectronon user manual sections **Advanced Data Analysis 1-3**. The Spectonon custom plugin manual discusses how to implement user-written algorithms into Spectronon, enabling custom data analyses.

3.1 Spectronon Tools

To open a datacube, select *File* → *Open Datacube*.

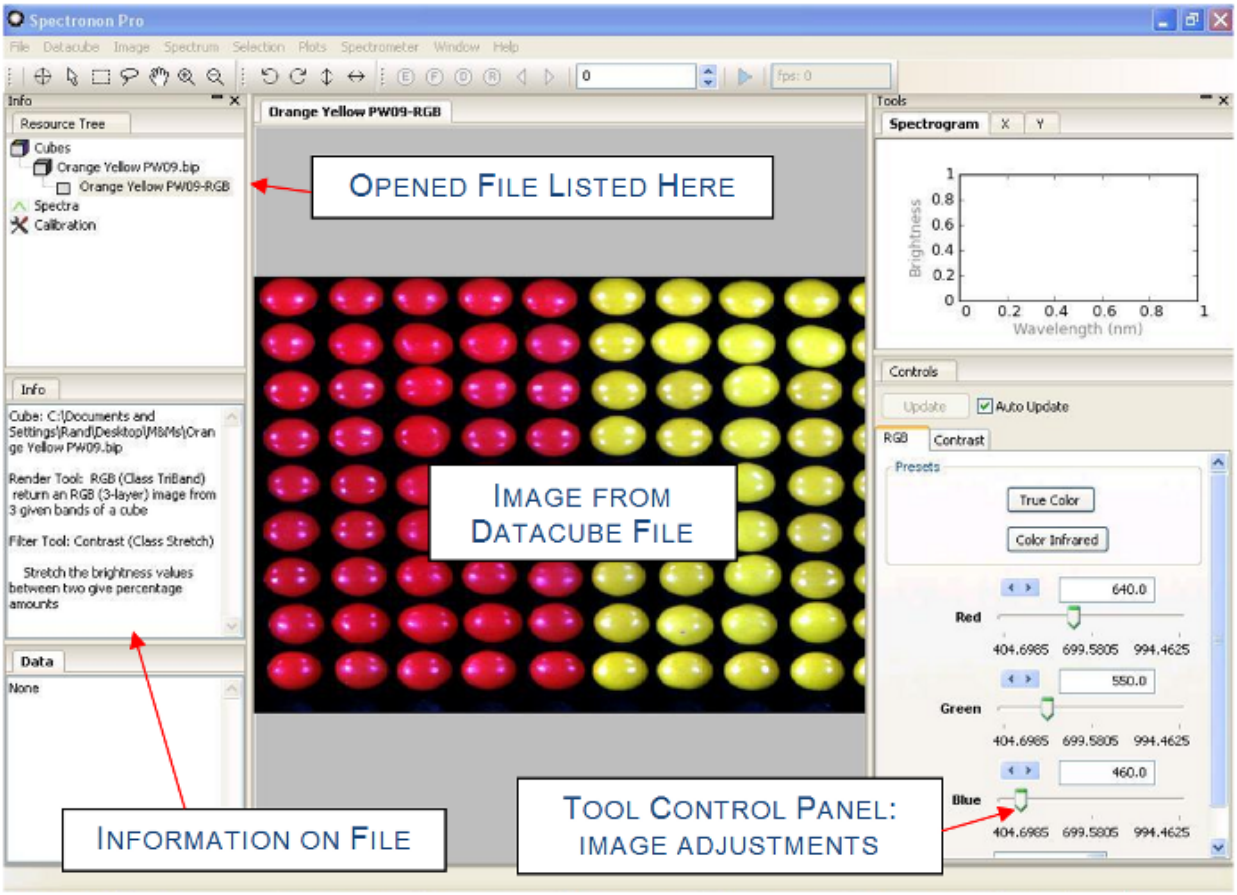


This will open a dialog that allows you to browse to find your datacube. Select your datacube and click on *Open* to load your datacube. This will result in the following:

- An image of your datacube will appear in the image panel
- A listing of the open datacube will appear in the Resource Tree
- Tabs will appear in the Parameters window that allow you to change the image (more on this later)
- Header information on your datacube will appear in the information panel

Note: Spectronon can open any datacube with an ENVI© formatted header. This includes .bip, bil, and .bsq formats.

This chapter employs an example datacube of M&M® and Reese's® Pieces candies. (This datacube can be downloaded from Resonon's website at http://downloads.resonon.com/.) By default, the datacube is opened with a true color image of the data, which approximates the appearance of the object under normal lighting conditions by combining red, green, and blue wavelengths from the datacube.

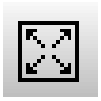


With a few minutes of practice using the available tools, you will be able to manipulate and visualize hyperspectral data quickly and efficiently.

3.2 Zoom, Pan, Flip, and Rotate Tool

To zoom to a specific area of the image, select the *magnify* tool in the toolbar and the cursor will change. Click the *magnify* tool in the image, and the view will zoom in. It is also possible to click and drag a selection within the image to zoom into the selected area.

To zoom out, select the *demagnify* tool and click anywhere in the image.

 To zoom all the out and recover the original image, select the *original size* tool and click anywhere in the image.

The user may also zoom in and out using the mouse scroll wheel, if available.

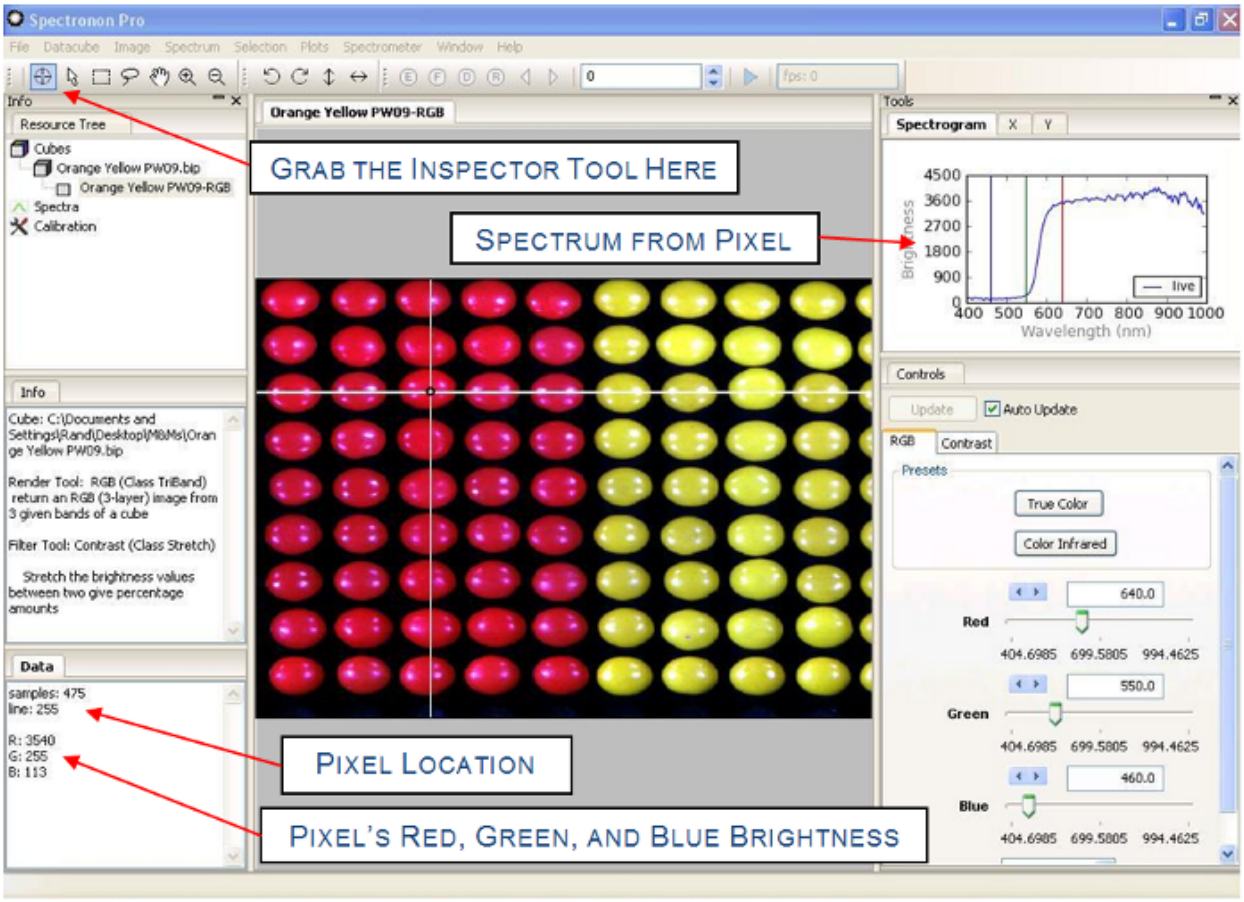
 To pan the image while zoomed in, select the pan tool. Click and drag inside of the Image to pan.

 Click these tool to rotate left, rotate right, flip vertically, or flip horizontally the image.

3.3 The Inspector Tool – Spectral Plots

 The *inspector* tool allows you to see the spectrum associated with a pixel. Choose the *inspector* from the toolbar, and then click a point inside the image. This will:

- Plot the spectrum for the pixel in the *spectrum plot panel*
- List the pixel location (sample and line number) in the *data panel*
- List the red (R), green (G), and blue (B) brightness values in the *data panel*



Click on other pixels to see the spectra from other pixels, click and hold while dragging the *inspector* tool to update the *plot panel* continuously.

The red, green, and blue vertical lines in the *spectral plot* indicate the hyperspectral wavelength bands used to generate the current image.

3.4 Region Of Interest (ROI) Tools

It is often useful to consider a group of pixels within the image. The ROI tools enable this capability and provide a number of options. As will be seen later, the ROI tool is often used during one of the first steps in classifying different objects within a hyperspectral image.

To select a Region of Interest (ROI), select either the *marquee*  , *lasso*  , or *flood fill* (wand)  tool from the menu bar. Click and drag a rectangle of interest with the *marquee* tool, or click and drag any closed shape with the *lasso*. The floodfill tool can be used to select a contiguous region of spectrally similar pixels. After selecting an area, right-click to reveal a pop-up menu with several options. Holding control while selecting ROIs allows you to append to the existing selection.

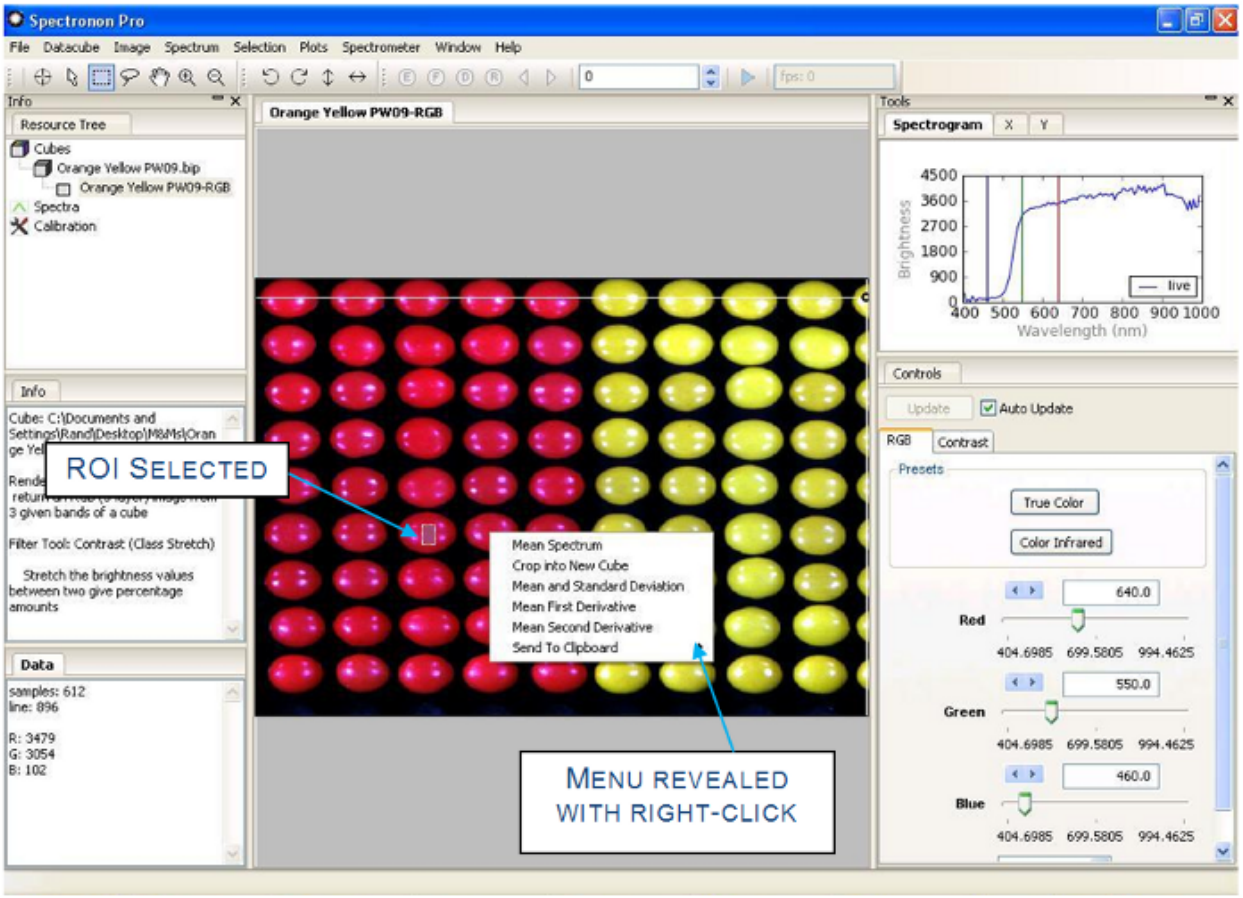
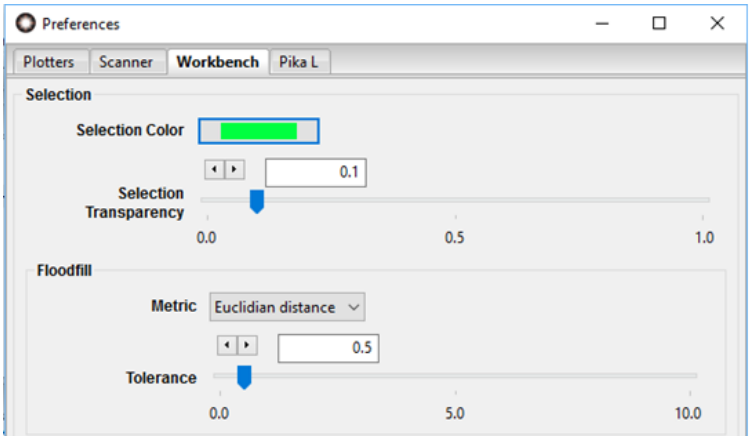


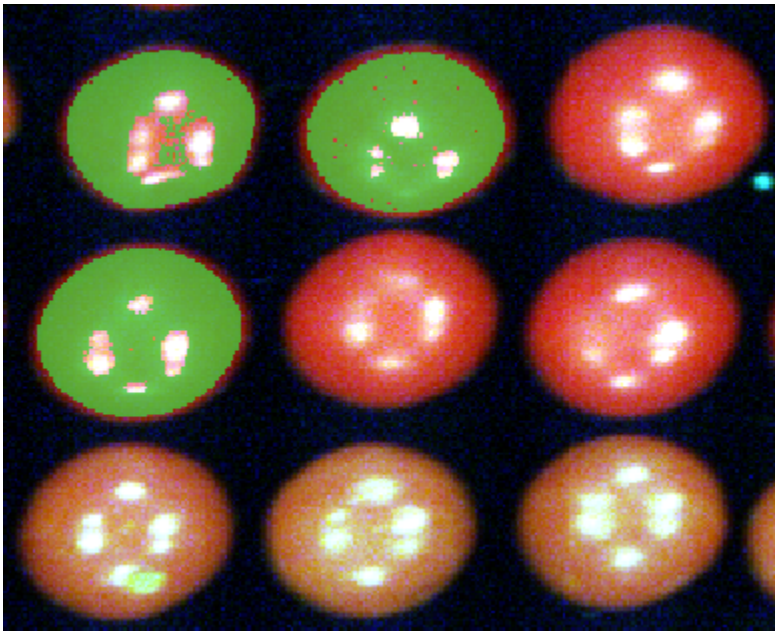
Fig. 1: **A small ROI on one of the red candies has been selected and a right-click has revealed the popup selection menu.**

Hint: The *selection* menu is also available in the main menu.

The *floodfill* tool shows pixels that are spectrally similar to the chosen pixel. Spectral similarity is assessed with either Euclidean distance or Spectral Angle Mapper (SAM), along with a tolerance value. The user can set these options by accessing the *Workbench* tab from *File* → *Preferences* menu.

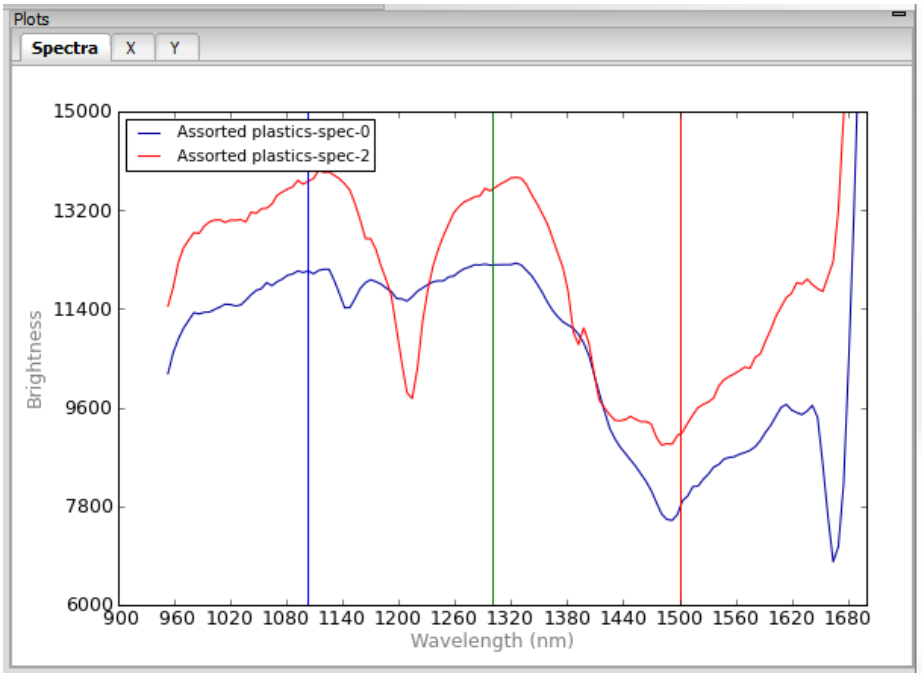


The use of the *floodfill* tool depends on an adjustable tolerance parameter. Floodfill operates on a representation of the datacube scaled from zero to one in each band. It calculates the Euclidean distance or SAM angle in spectral space between the clicked pixel and all contiguous pixels and expands the selection until the selected area contains all of the contiguous pixels for which the spectral distance to the clicked pixel is less than the selected tolerance. Increasing the tolerance will result in a larger selected region with greater spectral variability within that region (i.e. it allows pixels that are less similar to the clicked pixel to be included in the selection). Decreasing the tolerance will result in smaller selected regions with greater spectral similarity. As with the other selection tools, holding control while using the floodfill tool will allow a selection to be built up through multiple clicks of the tool.



An ROI consisting of multiple parts of the image has been selected by using the floodfill tool several times.

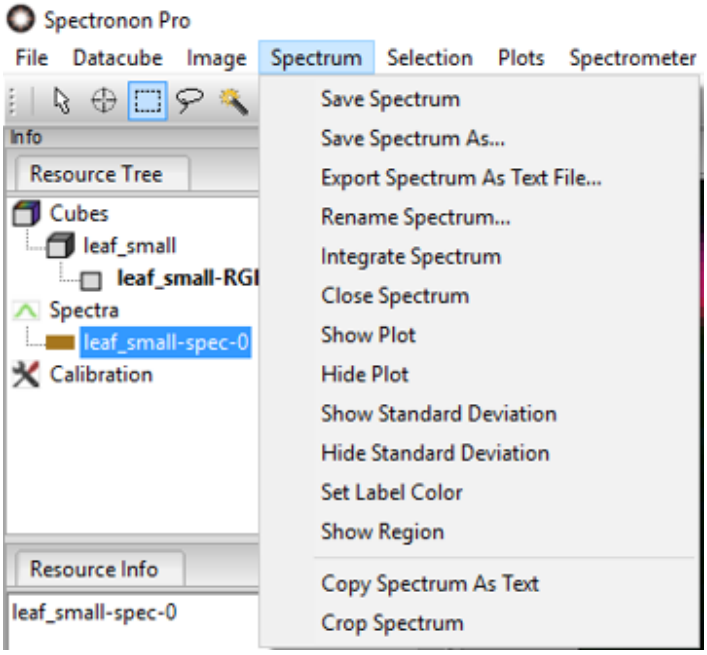
One of the most useful selection options is *mean spectrum*. (Descriptions for the other ROI options can be found in *Basic Data Acquisition*.) Selecting the mean spectrum option calculates the mean spectrum of all the pixels within the ROI area you selected and plots the result in the spectral plotter. Standard deviation can be shown as an envelope around the spectrum plot. Show or hide the standard deviation envelope with the **Show / Hide Standard Deviation** menu items.



Individual spectra can be selected by clicking on the graph of the spectra. You can crop an individual spectrum by selecting it, selecting a rectangular region in the *plot window*, right clicking to bring up the menu, and selecting *crop spectrum*. You can also set the range of the plot by selecting *Plots* → *Spectral Plotter* → *Set Range*.

Hint: To examine the plots in more detail, you may resize the plot panel boundary by dragging the edges. Alternatively, click on the *magnify tool*, then click or drag in the *spectral plotter* to zoom in. The *pan* tool will allow you to pan within the *spectral plotter* as well.

Selecting *Mean Spectrum* creates a new entry in the *resource tree* under a new heading, *spectra*. Right-clicking on the spectrum in the *resource tree* or selecting *Spectrum* from the menu bar will reveal a menu of options. Some of the most used options are listed below.



Save Spectrum

Change the name and save the spectrum as a file.

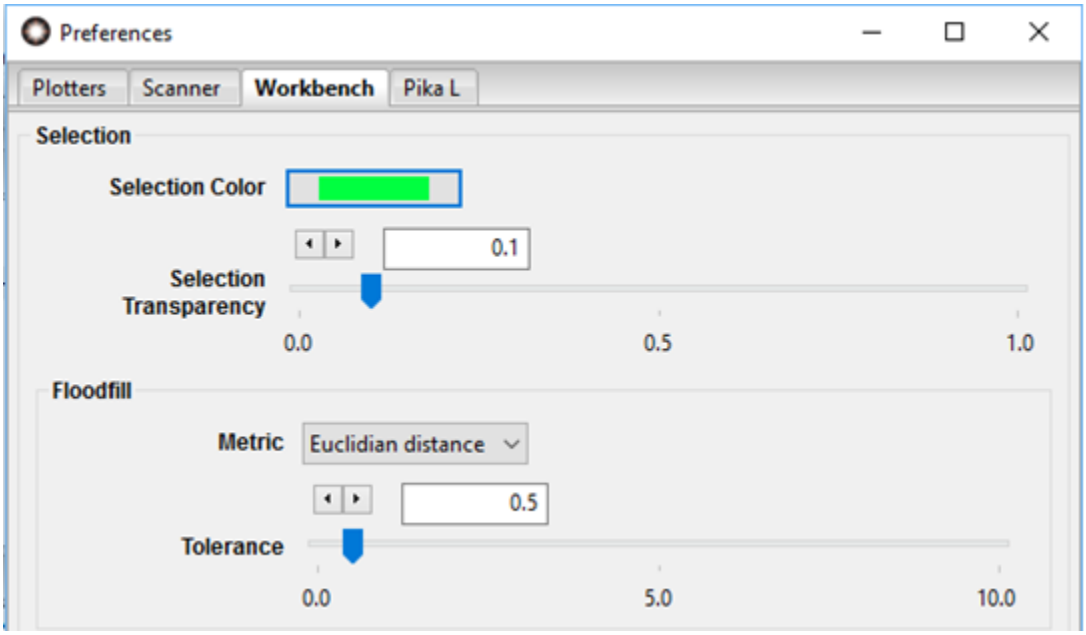
Set Label Color

Open a color picker dialog to change the label color of the spectral plot, and as shown later, classification areas based on this spectrum.

Show Region

Show the originally selected area for the ROI in the current image. This option is useful after you have selected several ROIs.

The color and transparency of the selection can be modified by selecting *File* → *Preferences*. The selection options are located in the *workbench* tab of the preferences window. A selection transparency of 1 represents a completely transparent selection (the selection will not be visible), while a selection transparency of 0 represents a completely opaque selection (the underlying render of the datacube will not be visible through the selection).

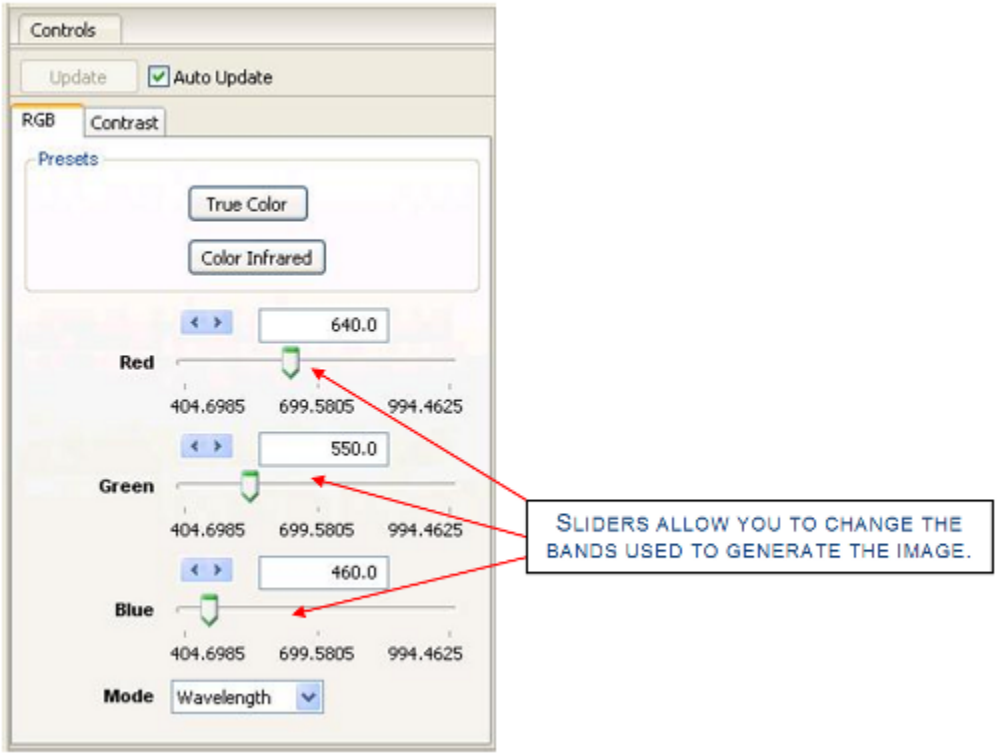


3.5 Image Visualization

Hyperspectral data can be visualized in far more ways than conventional color images. Image controls are provided in the tool control panel.

By default, the image is displayed in *True Color*, which means three representative bands are used to generate a red-green-blue (RGB) image, approximating how it appears to a human eye. The *Color Infrared* preset option provides a false-color RGB image with the red band set to an infrared wavelength. This option is useful for live vegetation datacubes.

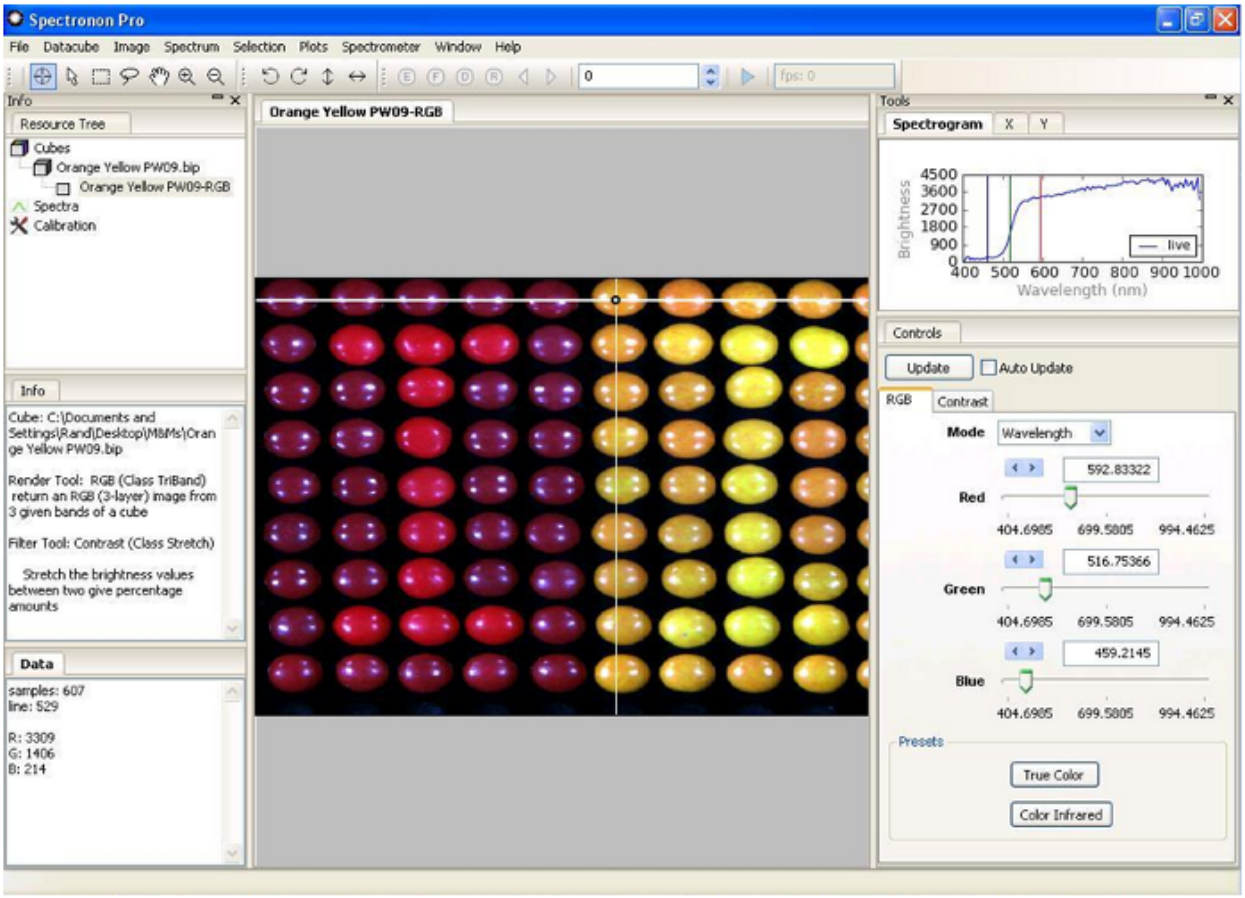
Any time you wish to restore the image to true color, simply click on the *True Color* button under *Presets*.



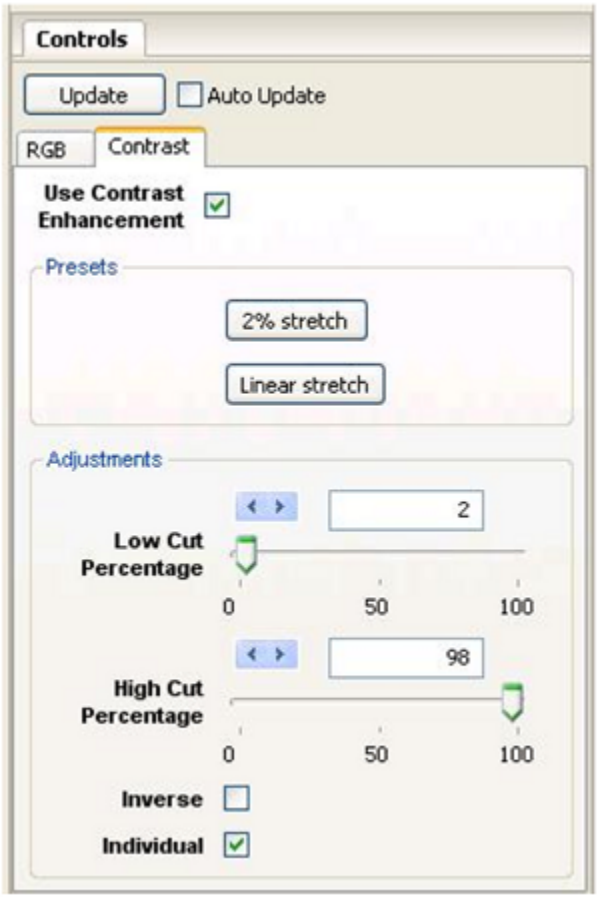
To generate false color images, use the sliders or arrows to change the wavelength bands used to create the RGB Image. This tool is often useful when trying to visualize specific spectral features associated with an object in your image. If *Auto Update* is not selected, click Update to generate the new image.

The *Mode* menu allows you to identify the band by wavelength (typically the most useful), or by band number.

As an example, of how false-color images can reveal interesting features, move the red slider to approximately 593 nm, and the green slider to approximately 516 nm, then click *Update*. This generates a new false-colored image, shown below, that reveals there are actually two kinds of red candy, and suggests there are two kinds of yellow candy – each candy type is positioned in the shape of an **"I"**. In the Spectronon user manual section **Advanced Data Analysis 2: Hyperspectral Classification** a classification technique shows this more clearly.



Note: The Red, Green, and Blue vertical lines in the Spectral Plot show the location of the bands chosen to create the false-color RGB image.



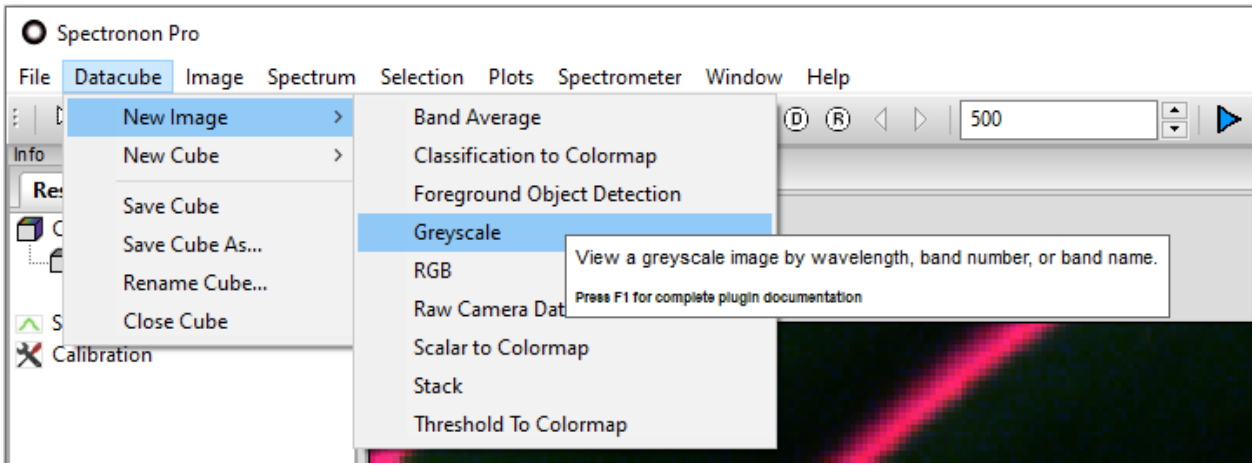
The *Contrast* tab in the tool control panel allows you to adjust the image contrast. If *Use Contrast Enhancement* is not checked, no image enhancement will be done and the tools in the Contrast tab will be not be active.

Note: Contrast enhancement does NOT change the hyperspectral data. It only changes the way the image appears.

Generally, contrast enhancement is beneficial. The *2% stretch* is the default, and it sets the darkest 2% of the pixels in the image to a value of 0, and the brightest 2% of the pixels in the image to maximum brightness (255). This choice minimizes the impact of glare. You can customize the percentage of the dark pixels set to 0 and the percentage of the bright pixels set to 255 with the sliders. The *Linear stretch* option sets these percentages to zero.

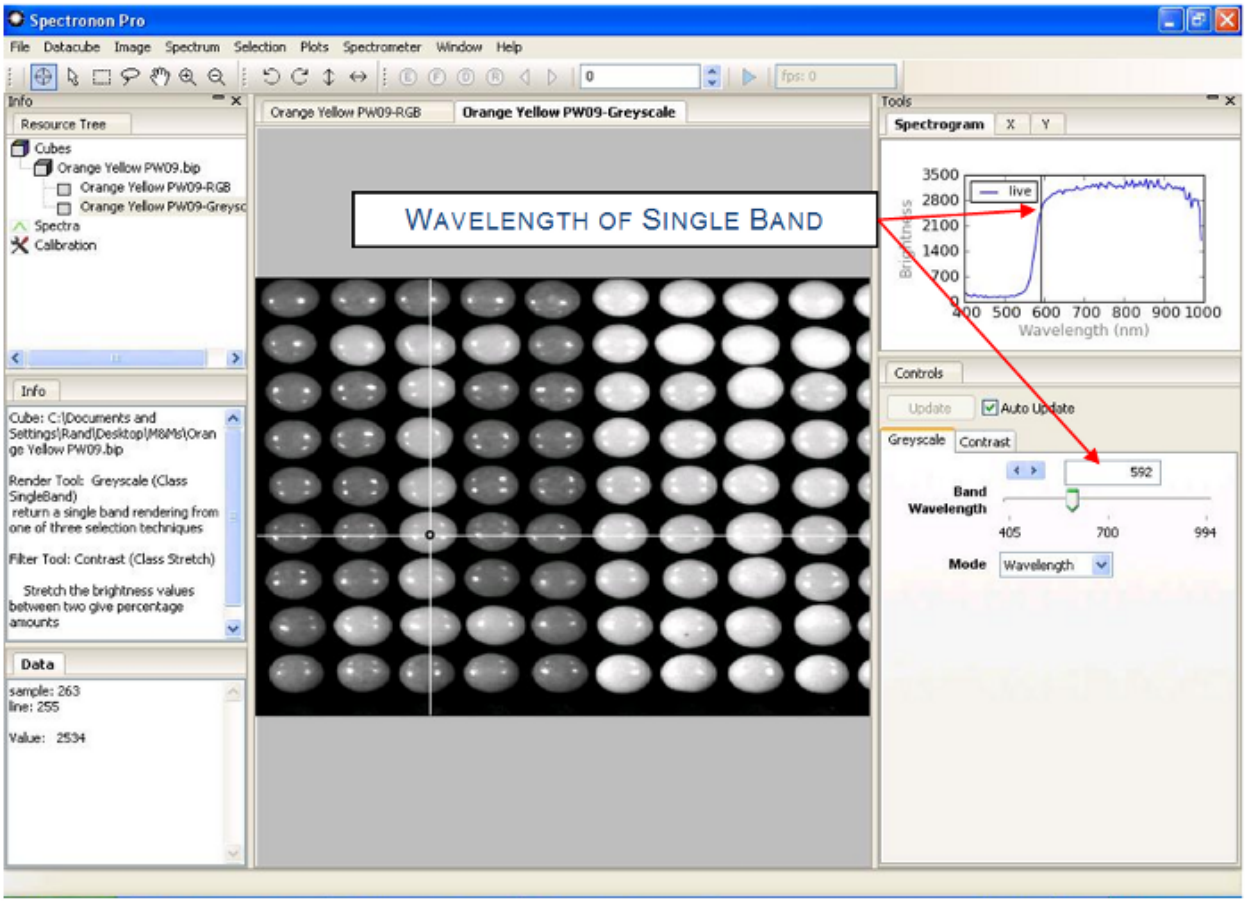
The *Inverse* checkbox is useful if you wish to highlight dark pixels.

The *Individual Bands* checkbox controls whether the brightness levels of the three image layers are considered all together or as individual layers.



It is often useful to view a single band in a standard grayscale (black-and-white) image to visualize the impact of a single spectral feature. To do this, go to the main menu and select *Datacube* → *New Image* → *Greyscale*.

The controls are similar to the RGB controls. If *Auto Update* is not checked, be sure to click *Update* after moving the slider to see the grayscale image for a new band.



As with the RGB images, a vertical line in the Spectral Plot shows the band you have chosen. Note that even though the image is from a single band, the Inspector and ROI Tools will continue to plot and operate on all wavelengths.

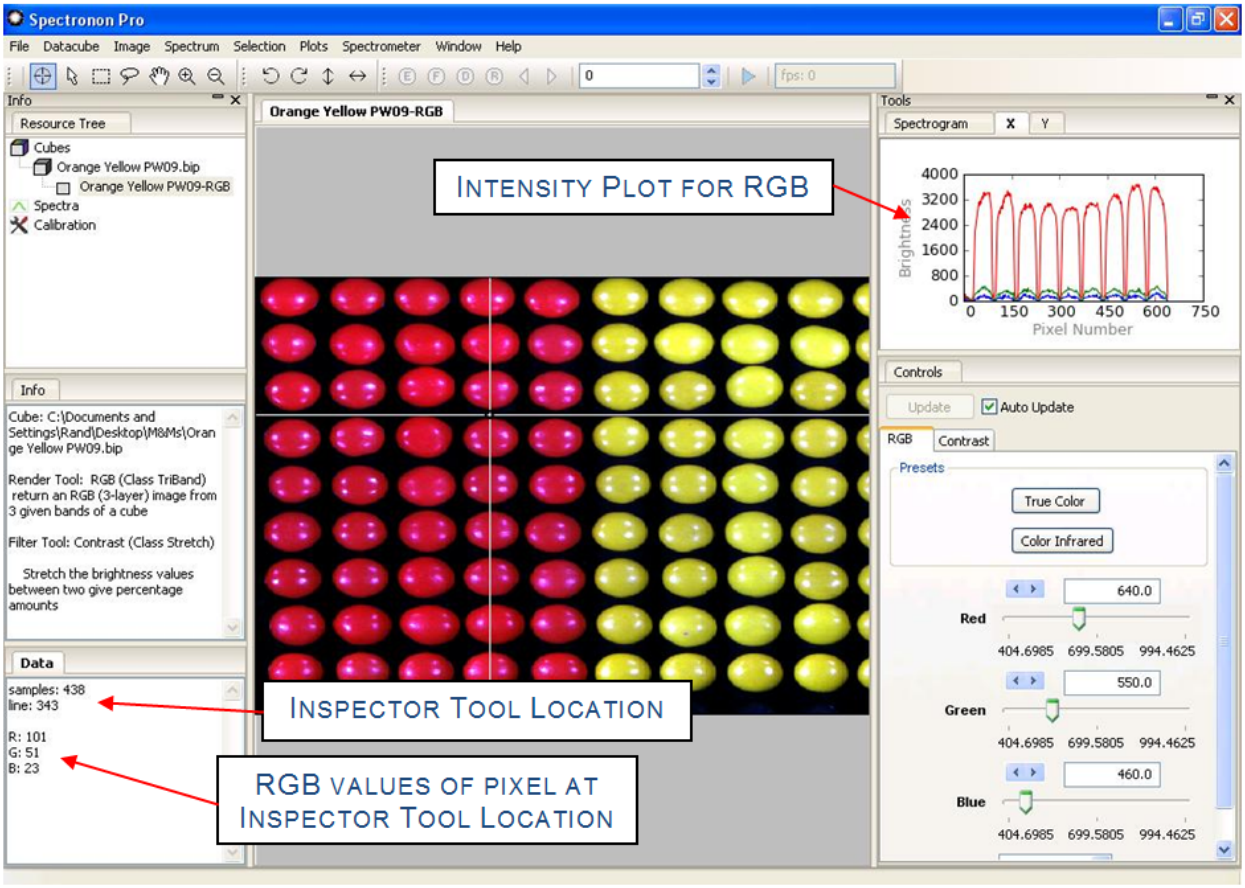
Hint: With *Auto Update* selected in the tool control panel, you can quickly scroll through single band images.

Warning: For large datacubes or slow computers, the *Auto Update* refresh rate may be slow.

3.6 Plot Panel

The plot panel allows you to visualize hyperspectral data graphically. This has already been seen with the use of the Inspector and ROI tools, but here we explore the plot panel in more detail.

The plot panel has three tabs: *Spectra*, *X*, and *Y*. These three tabs provide you with plots along the three axes of a datacube using the Inspector Tool  , as shown below.



Clicking on the *X* and *Y* tabs in the plot panel accesses the corresponding cross-sectional plots. The plot will show the intensity versus position value for the RGB bands used to create the image or the Grayscale band if used with a grayscale image.

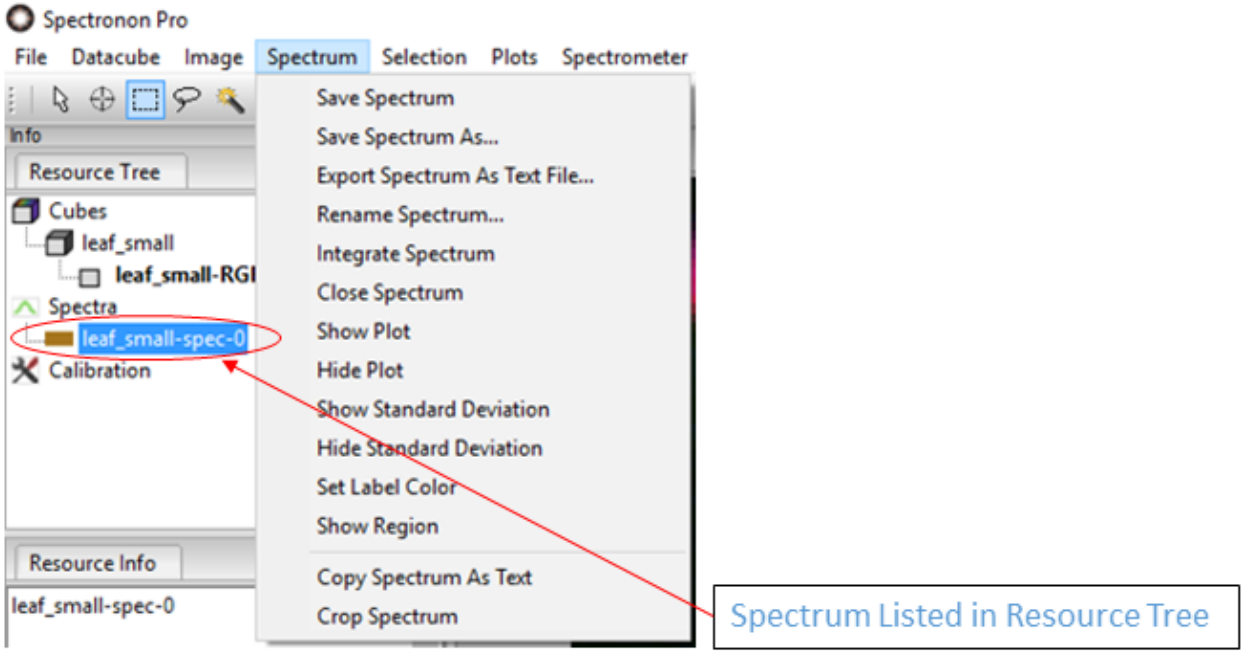
Note: The direction of *X* and *Y* depends on the orientation of your cube. Moving the *Inspector Tool* should reveal which axis you are plotting.

Hint: Use the *magnify tool*  , the *demagnify tool*  , and the *pan tool*  in the spectral plotter to navigate and examine features.

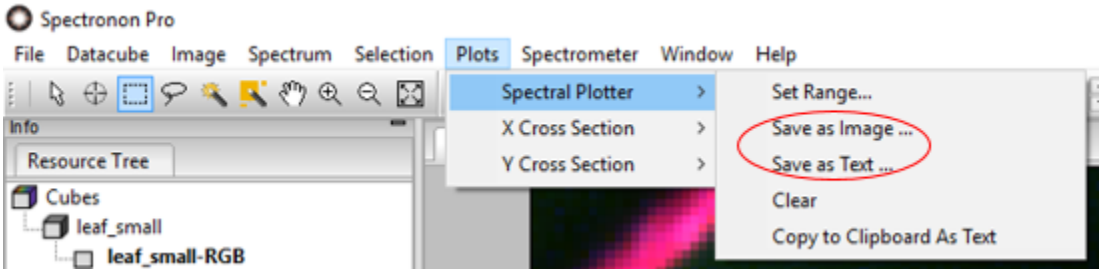
3.7 Saving Spectra, Plots, and Images

Spectronon makes it easy to save the results of your work for further investigations or for making presentations.

To save a spectrum, click the spectrum you wish to save in the *Resource Tree*, and then you may either (1) use the *Spectrum* menu in the main menu, or (2) right-click on the spectrum in the *Resource Tree* to reveal the menu shown below. From this menu, select either *Save Spectrum* or *Save Spectrum As...* This will open a save dialog. Once saved, the new name will appear when the file is plotted in the spectral plotter, and the file can be re-opened for use in later sessions.

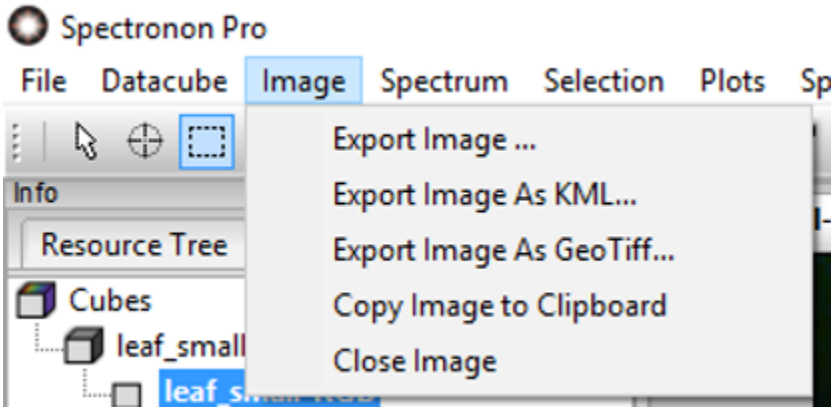


Select the menu option *Copy Spectrum As Text* to copy the data onto your clipboard, from which you can paste it into other applications such as Notepad and Excel.



To save a plot use the *Plots* menu as shown above. Select which plot you wish to save (*Spectral Plotter*, *X Cross Section*, or *Y Cross Section*), and then select *Save as Image* to save as an image or *Save as Text* to save the plotted data as tables in text file. Both options will pop up a save Dialog.

To Save an Image, select *Image* from the main menu, and then *Export Image…* This will pop up a save dialog.



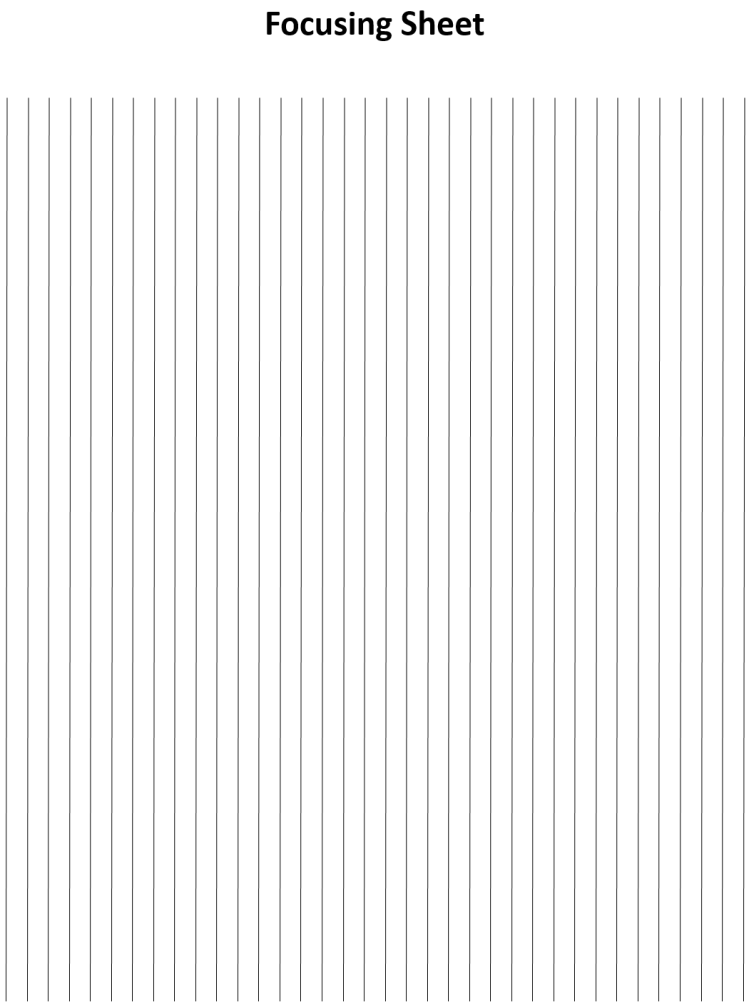
CHAPTER

FOUR

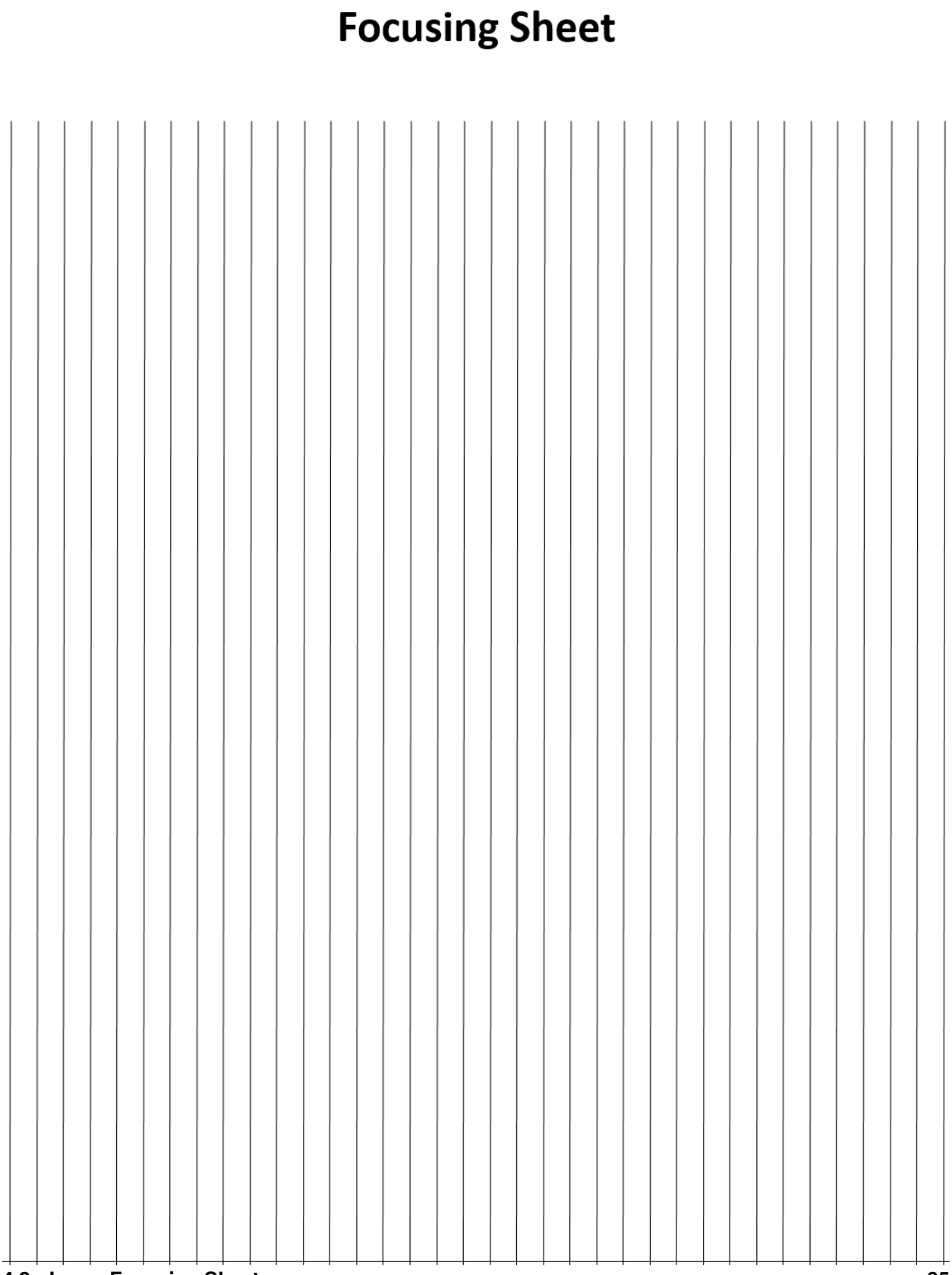
FOCUSING & CALIBRATION SHEETS

Use the focusing sheets to focus the objective lens, and use the aspect ratio calibration sheet to set the stage speed and imager framerate. See the *Basic Data Acquisition* for details.

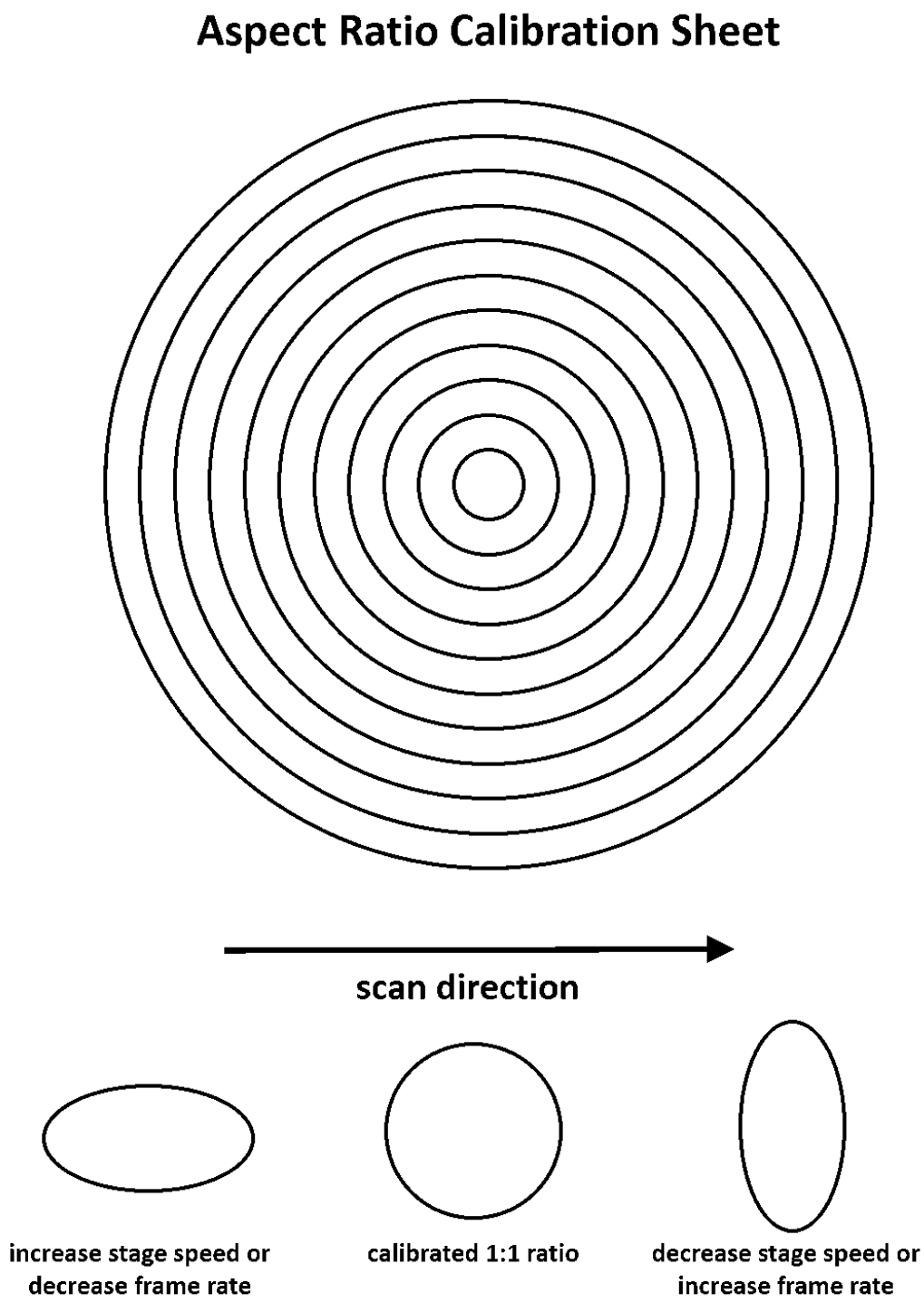
4.1 Small Focusing Sheet



4.2 Large Focusing Sheet



4.3 Aspect Ratio Calibration Sheet



CHAPTER

FIVE

RECALIBRATION SERVICES

Resonon recommends a yearly schedule for wavelength and radiometric calibration for best performance, or immediately after rough handling. Please contact us below for a quote and instructions.

CHAPTER

SIX

PRODUCT SUPPORT

Please contact Resonon by phone, email, or via the form on our website:

Phone: 1.406.586.3356
Website: https://resonon.com/support
Email: support@resonon.com

CHAPTER

SEVEN

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Resonon welcomes any recommendations regarding this manual. Customer feedback is always welcome as it helps us to continuously improve upon the quality of our products.

Please contact us at Resonon with any questions or comments. We look forward to hearing from you.